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A PROPOSAL FOR NATIONALLY APPROPRIATE MITIGATION ACTIONS (NAMAS) IN THE CEMENT SECTOR, IRON AND STEEL SECTOR AND MONITORING, REPORTING AND VERIFICATION

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Executive Summary

For more than five years, the Center for Clean Air Policy (CCAP) has been working with the Mexican government, primarily through the Ministry of Environment and Natural Resources (SEMARNAT), on the development of greenhouse gas (GHG) emissions mitigation strategies for Mexico. The latest phase of this work, funded by USAID through Abt Associates, was begun in April of 2010 and involves the design and implementation of nationally appropriate mitigation actions (NAMAs) for the cement and iron & steel sectors (these are two of the highest-emitting private sectors in Mexico), an analysis of the Mexican measurement, reporting and verification (MRV) system for GHG emissions, and some suggestions on how to adapt that system to greenhouse gas emission reduction.

The development of these NAMAs has required a significant amount of communication and negotiation between CCAP, SEMARNAT, and the cement and iron & steel chambers in Mexico (CANACEM and CANACERO, respectively). CCAP has negotiated the NAMA proposals with subgroups from each chamber, and with each change, a draft proposal was circulated for approval by all of the members of the respective chamber. Although this is a complex and time-consuming process, significant progress has been made in the development of NAMAs for each sector. The cement industry is very close to having a NAMA proposal ready to be presented to international donors for potential funding; an iron and steel NAMA proposal has gone through a number of iterations and is awaiting approval by CANACERO; and a description of a potential NAMA for MRV has been presented to SEMARNAT. These are each described more fully below.

The NAMA Proposal for the Mexican Cement Sector

Since the cement industry in Mexico is already among the most energy efficient in the world, the NAMA proposed for the cement sector consists of two sector-wide mitigation measures: lowering the average clinker factor of cement (also known as cement blending), and increasing the use of municipal waste materials (to replace petroleum coke). The cement industry in Mexico is committed to implementing these two measures. However, factors outside of the industry's control, such as the demand for blended cement and the supply of municipal waste could inhibit its ability to reach any agreed targets. As a result, the NAMA includes proposed actions by the Mexican government that can overcome these potential problems.

The primary issue related to cement blending is the lack of demand for blended cements. For example, current construction practices favor fast-setting Portland cement over slower-setting cements. To address this, the NAMA proposal includes a recommendation that the Mexican government require the use of blended cements in federally funded projects and take other steps to encourage greater demand for blended cements.

For alternative fuels, the industry's primary concern is the reliability of the supply of these fuels, which also requires government intervention to ensure. Solid waste supplies are currently under the jurisdiction of municipalities. However, municipal

administrations change every three years, and there is no obligation for future elected officials to be bound by commitments made by earlier administrations. Long-term, binding contracts are needed to ensure that sufficient quantities of waste products are turned into alternative fuels and provided to the cement industry and to specify the responsibilities (e.g., in terms of waste collection, processing, transportation, etc.), as well as the financial arrangements (e.g., fuel pricing, infrastructure costs), among the Parties to the agreement.

Therefore, the NAMA proposal for cement includes three basic elements: (1) mitigation actions to be taken by the cement industry, (2) facilitating actions to be taken by the Mexican government, and (3) financial or other support to be provided by the international community. Future work should focus on completing elements (2) and (3).

1. Cement industry actions

The cement industry in Mexico has agreed to the following mitigation actions (contingent upon international assistance):

- Reducing its average sector-wide clinker factor; and
- Increasing its average sector-wide fuel share for alternative fuels – tires and municipal solid waste (MSW).

Achievement of the targets proposed to date (but still subject to negotiation) would reduce fossil fuel use by about 12% in 2020 and 33% in 2030.

Specific cement companies and/or cement plants will also enter into contracts with the Federal government, various municipalities, and international donors to ensure that reliable supplies of alternative fuels are produced and utilized by the cement industry. These contracts will spell out the specific responsibilities and financial obligations of each of the parties and will be structured in a manner that is equitable to all parties to the contracts. Two principal options are under evaluation: 1) municipalities take responsibility for collecting, treating, and delivering the waste to cement companies for a specified price per ton (with international financing); or 2) municipalities pay cement companies to take the waste, and international finance allows the companies to construct the needed processing facilities and utilize the waste at a reasonable cost to the companies.

2. Government initiatives

The Mexican government (either SEMARNAT or another appropriate entity) would:

- Develop and enforce minimum blending standards to be used in many construction projects that are fully or partially funded with Federal funds;
- Require that buildings must incorporate blended cements to qualify for Mexico's green mortgage program;
- Engage in further efforts to increase public awareness of the qualities and characteristics of blended cements and to promote their use; and
- Condition other infrastructure finance to municipalities on municipalities' honoring long term agreements with cement companies to provide them with

ready-to-burn alternative fuels or to supply municipal waste, once the cement companies have invested in processing facilities.

3. International assistance

International donors will be sought to provide financial or other support, as needed:

- To reduce the cost of exploration and development of new sources of cement blending materials; and
- To reduce, to economically viable levels, the capital and other costs required to process tires or MSW into alternative fuels that can be used in cement kilns (e.g., construction of processing and storage facilities, new equipment, transportation, etc.). A combination of loans, grants, and risk guarantees will likely be used.

This proposal is designed to produce a supported NAMA in a key sector in Mexico that can help the country to achieve its ambitious goals to reduce its greenhouse gas emissions. Full achievement of the targets would produce emissions reductions for the cement sector of about 9% of the business-as-usual (BAU) direct emissions level in 2020 and about 15% of the BAU direct emissions level in 2030.

To complete a viable proposal for donors, further development of this NAMA is needed. The cement industry has agreed to take targets for cement blending and alternative fuel use as described above but would like to include other forms of low-carbon alternative fuels (such as sewage sludge). Once the targets are finalized, then a full financing and implementation plan must be agreed for each of the two elements of the NAMA, and specific contracts will need to be finalized between cement companies, the Mexican government, participating municipalities, and the international donor.

The NAMA for the Iron and Steel Sector

The iron and steel industry in Mexico is also quite energy efficient and is expected to grow rapidly over the next twenty years. Thus, while the NAMA proposal for this sector does include some improvements in energy efficiency at existing plants, the focus is on lowering the carbon intensity of yet-to-be-built facilities. However, this NAMA is still being negotiated, and Mexico's iron and steel industry has not yet agreed to any of the potential NAMA measures proposed by CCAP.

There are three basic processes for producing iron and steel – a blast furnace coupled with a basic oxygen furnace (BF-BOF), direct reduction of iron coupled with an electric arc furnace (DRI-EAF), and coupling scrap iron input with an EAF (scrap-EAF). BF-BOF facilities are generally coal-based, while DRI facilities usually use natural gas (although some in India burn coal). Mexico is the world leader in the use of DRI (and in fact developed this technology), which is much less emissions-intensive than BF-BOF.

Therefore, the focus of the steel NAMA is to provide incentives that encourage the growth of the industry to follow a low-carbon emissions pathway without providing a competitive advantage to any specific companies.

The current proposal for a NAMA for the Mexico iron & steel sector includes the following recommendations for potential components:

- Carbon intensity performance standards for new facilities, defined in terms of tons CO_2 per ton Crude Steel. There would be separate standards, to be negotiated between the Mexican government and the steel industry, for ore-based facilities (less than 50% scrap) and scrap-based (more than 50% scrap).
- Government assistance to help facilities achieve the agreed performance standards, including:
  - Limited-term subsidies, partially funded through international assistance;
  - Backing for long-term, market-rate contracts for natural gas; and
  - Establishment of a program for qualifying and awarding domestic offsets through projects such as wind farms and improved forest management.
- A demonstration-sized CCS facility, partially financed with international funds, at one of Mexico's iron and steel plants.
- Energy (or carbon) audits at all existing iron and steel facilities and energy (or emissions) management systems at all new and existing facilities.

The NAMA proposed for the Mexican iron & steel industry is estimated to achieve emissions reductions on the order of 6 million metric tons CO_2 (about 12% of BAU) in 2020. The largest cost is expected to be the subsidies for new facilities beginning construction between the time the NAMA is implemented and 2020 to meet the new source carbon-intensity performance standards. CCAP estimates that these (undiscounted) costs would range from about $4 million in 2011, to $40 million in 2020, and back down to $1 million in 2029.[1] These payment levels reflect projected growth trends in the industry and assume that facilities are compensated for the emissions difference (at $15 per ton) between the average new plant and the state-of-the-art plant of the same type. Other costs are expected to include capacity building for the Mexican government and auditors, assistance to small companies to pay for audits and implementation of mandated action plans, and incremental costs of carbon capture and sequestration at one facility. A substantial portion of these costs would be compensated by the international community.

The MRV NAMA

Mexico has a number of programs under which industrial facilities or companies report their GHG emissions. Facilities in eleven economic sectors are required to report their GHG emissions to the Registry of Emissions and Transfers of Contaminants (RETC), but these reports are not verified and provide minimal information about the methodologies

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[1] These figures reflect a proposal to pay the full incentive level for five years and a declining incentive level for the next five years. If payments are instead made at a constant level each year for ten years, assuming a discount rate of 10%, the payment would be about $32 million per year from 2011 to 2020.

used to calculate emissions (however, the reporting requirements have recently been revised to be more complete). Programa GEI is a voluntary program run by SEMARNAT in which companies report their annual GHG emissions using WBCSD/WRI protocols for measurement of emissions. Most of the major industrial players in Mexico belong to this program. GHG emissions in Mexico are also reported in their National Communications to the UNFCCC and through various government publications and agencies. All of the parties that CCAP consulted in Mexico that are involved in these emissions measurement and reporting efforts expressed a keen interest in adopting a harmonized set of methodologies for measuring GHG emissions across programs and developing a consistent reporting format.

In terms of verification, there is an entity in Mexico known as EMA (Entidad Mexican de Acreditación), which is an internationally accredited body that currently trains auditors in Mexico to verify emissions of traditional pollutants. Using ISO standards, EMA has just begun a program to train and certify auditors of GHG emissions and GHG emissions reductions as well. From an international perspective, this could be quite groundbreaking, as it provides an opportunity for Mexico to implement a GHG emissions verification system that could serve as a model for other developing countries – a domestic system of verification of GHG emissions that also qualifies as "international verification," as generally stipulated under UNFCCC negotiations.

Overall, Mexico appears to have the basic pieces in place to construct an MRV system for industrial GHG emissions. The country just needs to coordinate and harmonize these pieces. Thus, CCAP has recommended a two-phase NAMA to develop an MRV system for industrial GHG emissions in Mexico.

The first phase, which we estimate could be completed in about six months, would involve a series of monthly workshops, and the primary participants, at least initially, would be officials from various agencies that are responsible for GHG emissions reports or for data that could be used for review of emissions reporting. These workshops would focus on:

- Prioritization of the sectors to include (at least initially) in the MRV program;
- Prioritization of the data required for MRV of GHG emissions;
- Standardization of the data systems used by the various agencies;
- Harmonization of the methodologies used to measure GHG emissions;
- Assessment of the capacity building and international assistance needed to standardize the data systems and harmonize the GHG measurement methodologies; and
- Further development of verification systems.

Phase II of this MRV NAMA would be longer term (1-2 years) and would involve obtaining the international assistance identified as a need in Phase I and then implementing the MRV system as designed in the earlier phase..

Lessons Learned

To close, CCAP has learned some general lessons regarding the development of NAMAs from this work in Mexico. The most important of these are:

- Data and MRV are key capacity-building needs. Data is needed to both accurately evaluate a reference level of emissions and to determine the mitigation potential and costs of mitigation measures. Good data will both reduce analytical uncertainties that inhibit the ability of a NAMA to garner international assistance and soften resistance of industrial players to make specific mitigation commitments. CCAP's experience in Mexico has made clear that industry is willing to commit to specific targets for the percentage of blending and the percentage share of fuels from waste materials. Industry is hesitant to commit to a specific future emissions reduction level from a sector without also reaching agreement on the current, facility-specific baseline level of emissions and the methodology for determining reference case emission levels (the BAU baseline) for 2020 and beyond. The uncertainty in the future levels of production in a growing economy is at the heart of the difficulty here.
- NAMA development and implementation can proceed at the same time that data systems are put in place. As the previous bullet point makes clear, it may be best to initially pursue NAMAs that are couched in terms of actions rather than GHG targets until good data is available.
- EMA-like institutions could serve as a basis for internationally accredited domestic verification for GHG emissions and emissions reductions.
- Even sectoral NAMAs are often not isolated within a single sector, as the Mexico cement NAMA demonstrates. Greater use of alternative fuels will affect both the oil industry that supplies their current fuels and the municipal waste sector, and cement blending obviously impacts the construction industry.
- Most importantly, designing an implementation plan for a NAMA is a complex and time-consuming process, but it is the key to a successful NAMA. The design of a NAMA must look beyond cost curves and also focus on non-cost implementation barriers to mitigation measures and policies and programs to overcome these. For example:
  - Developing an implementation plan requires significant negotiation between government and sector officials, and the final NAMA will likely require significant government efforts – not just industry actions – to be successful.
  - Determining how best to put a NAMA in place must take into account the potential creation of winners and losers within a sector, especially because small, domestic companies in developing countries may be disadvantaged by certain mitigation programs.
  - And of course, the cost of a NAMA will depend upon the stringency of the targets and the implementation scenario and will therefore affect the need for and ability to obtain international assistance.

NAMAs for the Mexican Cement Sector[2]

Overview of the Mexican Cement Sector NAMA

This proposal describes a supported NAMA (nationally appropriate mitigation action) for reducing CO_2 emissions from the cement sector in Mexico. The basic elements of the proposal are: (1) mitigation actions to be taken by the cement industry, (2) facilitative actions to be taken by the Mexican government, and (3) financial or other support to be provided by the international community. These are each described briefly below.

1. Cement industry actions

The cement industry in Mexico will strive to reach the following mitigation targets:

- An average sector-wide clinker factor of 72% by 2020 and 68% by 2030; and
- An average sector-wide fuel share for alternative fuels – tires and municipal solid waste (MSW) – of 8% in 2020 and 21% in 2030.

Specific cement companies and/or cement plants will also enter into contracts with the Federal government, various municipalities, and international donors to ensure that reliable supplies of alternative fuels are produced and utilized by the cement industry. These contracts will spell out the specific responsibilities and financial obligations of each of the parties and will be structured in a manner that is equitable to all parties to the contracts.

2. Government initiatives

The Mexican government (either SEMARNAT or another appropriate entity) will:

- Develop and enforce minimum blending standards to be used in all construction projects that are fully or partially funded with Federal funds;
- Require that buildings must incorporate blended cements to qualify for Mexico's green mortgage program;
- Engage in further efforts to increase public awareness of the qualities and characteristics of blended cements and to promote their use;
- Modify standards for waste disposal (or create new standards), as needed; and
- Undertake any obligations required by the alternative fuels contracts described above.

3. International assistance

International donors will be sought to provide financial or other support, as needed, for:

- Exploration and development of new sources of cement blending materials; and
- Capital and other costs required to process tires or MSW into alternative fuels that can be used in cement kilns (e.g., construction of processing and storage facilities, new equipment, transportation, etc.).

Overall result: This proposal is designed to produce a supported NAMA in a key sector in Mexico that can help the country to achieve its ambitious goals to reduce its greenhouse gas emissions.

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NAMAs for the Mexican Cement Sector

Overview of NAMAs

The concept of Nationally Appropriate Mitigation Actions, or NAMAs, was first raised under the Bali Action Plan, for both developed and developing countries. Developing countries agreed to take "[n]ationally appropriate mitigation actions … in the context of sustainable development, supported and enabled by technology, financing and capacity-building, in a measurable, reportable and verifiable manner." This phrase has been interpreted to mean that both the NAMAs (undertaken by developing countries) and the support (provided by developed countries) are subject to measurement, reporting and verification (MRV). Under the Copenhagen Accord, developed countries agreed to provide "scaled up, new and additional, predictable and adequate funding … to developing countries … to enable and support enhanced action on mitigation, … adaptation, technology development and transfer and capacity-building," including amounts "approaching USD 30 billion for the period 2010 – 2012."

The NAMA framework establishes a process for developing countries to adopt climate mitigation actions appropriate to their own circumstances. NAMAs can be government regulations, standards, programs, policies or financial incentives that require or encourage individuals, organizations, companies, industries, or governments to undertake mitigation actions. NAMAs can cover one or more sectors or portions of sectors, and more than one NAMA can be proposed in a sector. For a given industry sector, development and implementation of NAMAs offers an opportunity for international funding to support a lower carbon growth path. Developed countries are expected to steer funds to NAMAs that represent a clear and substantial reduction from business-as-usual (BAU) emissions.

There are three general categories of NAMAs: 1) unilateral; 2) supported/cooperative; and 3) credit-generating. These categories are differentiated on the basis of who pays for implementation and who takes credit for making the associated reductions. **Unilateral NAMAs** are autonomous actions taken by developing countries to achieve emissions reductions without outside support or financing. **Supported/Cooperative NAMAs** are developing-country actions undertaken with financial or other support from developed-country Parties to cover the incremental costs, which result in more aggressive emissions reductions than unilateral NAMAs. **Credit-Generating NAMAs** are actions that build upon supported NAMAs and produce offsets for sale in the global carbon market, once emissions fall below an agreed crediting baseline.

Mexico Context

Mexico is a world leader in its efforts to address climate change. Through its national climate plan (the PECC), Mexico has already established a number of mitigation actions that it plans to take that will reduce its total annual greenhouse gas (GHG) emissions by 51 $MtCO_2e$ by 2012 (about 6-7% of BAU). The PECC also establishes some very ambitious medium-term and long-term mitigation goals (e.g., a reduction in GHG emissions of 70% of BAU – to 50% of the emissions level in 2000 – by 2050).

In an Annex to the Copenhagen Accord, Mexico also stated that it "aims at reducing its GHG emissions up to 30% with respect to the business as usual scenario by 2020, provided the provision of adequate financial and technological support from developed countries as part of a global agreement."

Thus, Mexico has established aggressive goals for reducing its GHG emissions, if sufficient international assistance is provided to help it attain these objectives. This NAMA proposal is designed to provide an initial impetus to this process by: (1) recommending realistic mitigation goals and implementation strategies in one of Mexico's most important industrial sectors, and (2) providing enough information that the interest of international donors in supporting this NAMA can be gauged.

Cement-Sector Context

The production of cement is a very energy-intensive and greenhouse gas-intensive process. CO_2 emissions from cement production come primarily from three main sources: direct emissions from fuel combustion, indirect emissions from electricity use, and process emissions from the production of clinker, the base ingredient of cement. Substantial CO_2 emissions are inherent to the clinker production process, as the calcination of the limestone releases over one-half a ton of CO_2 on average for each ton of clinker produced.

Mexico is a world leader in the efficient production of cement, so there are limited opportunities for reducing GHG emissions through energy efficiency. However, two other pathways – cement blending and alternative fuel use – provide significant potential for mitigating CO_2 emissions.

- ***Clinker and cement substitution (blending).*** The clinker produced in cement kilns is the main component in most types of cement, comprising up to 95 percent of the content of Portland cement. Fly ash, slag, and other materials that have cementitious properties (such as natural pozzolans) can substitute for some of this clinker. By blending or substituting these alternative materials into the cement, the "clinker factor" is lowered, and CO_2 emissions are lowered as a result of the avoided clinker production.

- ***Increasing use of alternative fuels.*** Kilns are typically fueled by fossil energy, such as coal, petcoke, and fuel oil. Some of these energy needs can be provided by less carbon-intensive alternative fuels, such as municipal solid waste (MSW), tires, biomass, or sewage sludge. By lowering the carbon intensity of the energy supply, these alternative fuels reduce CO_2 emissions.

Emissions Baseline

The baseline projections for cement production, clinker production, CO_2 emissions, and CO_2 emissions intensity that are used in this NAMA are as follows (the baseline assumes that clinker factor and alternative fuel use are constant at 78% and 0%, respectively):

Year	GDP (Billion USD)	Mt Cement	Mt Clinker	Mt CO2	tCO2/ t cement
2000	$780	33.2	25.9	23.1	0.70
2005	$849	37.5	29.3	28.1	0.75
2010	$913	43.5	33.9	31.1	0.72
2015	$1091	51.0	39.8	36.9	0.72
2020	$1319	59.1	46.5	42.0	0.71
2025	$1561	68.6	54.0	48.4	0.71
2030	$1811	79.5	62.0	55.9	0.70

The Proposed Mexico Cement-Sector NAMA

It is estimated that a fairly aggressive NAMA aimed at increasing the use of alternative fuels and increased clinker substitution (blending) could result in substantial reductions of CO_2, reduce the use of fossil fuels, and produce additional economic and environmental benefits. CANACEM, SEMARNAT and CCAP are proposing NAMAs for these two actions that, if successful would reduce Mexico's cement CO_2 emissions, relative to baseline projections, by about 9% of BAU in 2020 and 15% of BAU in 2030.[3]

1. The Cement Blending NAMA

The current clinker ratio per ton of cement in Mexico is 78%. **For the cement blending NAMA, we propose a target industry clinker ratio of 72% by 2020 and 68% by 2030.** Currently, the 20% of cement plants that do the most blending have a clinker ratio of 68%. The 2030 target is designed to get the whole industry to blend at least as much as the top 20% blend today.

The important factors that must be addressed to achieve these goals are:

- Increasing demand for blended cements, and
- Ensuring sufficient supplies of blending materials.

Unilateral Efforts

The demand for blended cements in Mexico is constrained by ingrained traditional construction practices and preferences for specific types of cements (e.g., fast-setting cements), concerns over liability, and a general lack of understanding and acceptance of blended cements by purchasers. To boost blending in Mexico, we are recommending that SEMARNAT or another appropriate arm of the government focus on inducing blended cement demand through new regulations, incentives and public awareness efforts. This should include three actions:

- Establish a requirement that all federal construction projects in the National Infrastructure Plan, and all other construction projects that are fully or partially funded by the Federal government, be built with cement at the minimum clinker ratio permitted by the projects' engineering requirements.
- The Federal government's Institute of the National Fund for Worker Homes (INFONAVIT) will include blended cement as a requirement for the homes eligible to participate in the green mortgage program (*hipoteca verde*).
- To further stimulate market demand for blended cements, further blending requirements will be established by the Federal government, which could include strengthening of existing blending minima for each type of project in which cement is used or adoption of a universal minimum for cement blending, with exceptions for specific applications (such as bridges).

In terms of the supply of blending materials, CCAP's initial analysis suggests that the known supply of blending materials in Mexico – typically pozzolans, slag and fly ash – may be

[3] Given uncertainties in the future growth of the cement industry and the corresponding GHG emissions baseline, these emissions reduction percentages from BAU are only indicative of those that could be achieved under the assumptions adopted for this analysis. They do not represent emissions reduction commitments by the cement industry. Actual emissions reductions will only be quantifiable ex-post.

insufficient to meet the proposed blending targets. Fly ash and slag volumes are relatively low due to the small number of coal-fired power plants and steel blast furnaces, respectively. Known pozzolan deposits are generally concentrated in the center of the country and current extraction rates are not high enough to provide the material needed to reach the blending targets proposed here; the overall extent of these deposits is also uncertain. Thus, increased pozzolan extraction rates as well as further sources of blending materials will likely be needed to meet the NAMA goals.

We believe that the Mexican government's unilateral actions described above will create significant incentives for the cement companies to improve blending. However, more data is needed on the availability and costs of blending materials to determine how cost-effective the proposed measures are for cement companies. Additionally, information on the composition and sensitivity of the cement market in Mexico is needed to quantify the impact of government demand on blended cement production.

International Support

International financial support could cover the costs associated with developing reliable supplies of blending materials. Such resources could be used for geological exploration in regions with potential pozzolan deposits, as well as technology to optimize the extraction rates. Blending material costs are also closely linked to location, as transportation of these materials can be quite expensive. International financial support could be used to help reduce these costs and to further ensure long-term, reliable sources of blending materials, as the local availability of blending materials is likely to diminish relative to demand.

Additionally, international assistance could fund workshops to educate government and other purchasers of cement on the qualities of blended cement. These workshops could be co-hosted by private-sector representatives from the industries that use the lowest clinker ratios in their blended cements, as many of these companies have an important presence in Mexico.

2. The Alternative Fuels NAMA

The cement sector in Mexico has been using liquid residues, solid residues and tires as alternative fuels for at least a decade. For the alternative fuels considered here, tires and municipal solid waste (MSW), current usage is about 0.7% and 0%, respectively. **Our 2020 target is to increase the share of these alternative fuels to 8% (3% for tires and 5% for MSW). The 2030 target would increase this total share to 21%, with tires use rising to 6% and MSW to 15%.** These targets are within the technical potential substitution rates for each fuel and allow some flexibility for the introduction of other alternative fuels like biomass, sewage sludge and industrial residues. The replaced traditional fuel is assumed to be petcoke, the most carbon intensive fuel and also the most widely used in the Mexican cement industry.

Tires are considered wastes that require special handling, while MSW is considered urban solid waste; therefore, the former falls under State jurisdiction and the latter under Municipal jurisdiction. However, most State laws delegate tire collection and processing to Municipalities. Municipalities are also in charge of the collection, transportation, treatment and final disposal of MSW. Local governments' standard practice is to make concessions to private parties to collect, transport, treat and dispose of this waste. However, municipal administrations change every three years, and concession contracts are often renegotiated upon a change in administration. This political process hampers the ability of cement companies to obtain constant and predictable long-term supplies of combustible waste products. In addition, the collected waste is not suitable for use by cement plants; it requires processing before it can be burned in a cement kiln, and the facilities needed to process this waste are not common in Mexico.

The primary barriers that must be addressed to increase the use of alternative fuels in Mexico are:

- constructing processing facilities to prepare waste materials for burning in cement kilns, and
- providing sufficient supplies of alternative fuels to cement plants.

Unilateral Efforts

To achieve the alternative fuel targets proposed here, a number of municipalities and cement companies (and perhaps the Federal government) will need to enter into contractual arrangements that clearly establish the responsibilities of each party. The primary objectives of these agreements will be to ensure that: (1) the parties investing in the equipment and infrastructure required to process the waste are provided with reliable, long-term supplies of wastes and markets for the alternative fuels; and (2) the cement plants are guaranteed a steady, long-term supply of alternative fuels. Two implementation options could be considered:

- an agreement under which the municipality is responsible for collection and processing of the MSW and tires, and the cement company then purchases the resulting fuel; or
- an agreement under which the cement company is responsible for the processing of the MSW and tires, but the municipality pays the cement company to take these materials after collecting them (a model for this is the use of sewage sludge and MSW as alternative fuels at the largest cement plant in Europe[4]).

To reach the 2020 target, such agreements could potentially involve as few as five cities and seven cement plants. For example, this goal could be reached if the maximum technical substitution rates for MSW (30%) and tires (20%) were employed at cement plants in the five municipalities that have sufficient supplies of MSW and tires as well as waste treatment experience (Chihuahua, Ensenada, Hermosillo, Juarez and Monterrey). The seven cement plants within these five municipalities represented 20% of energy consumption and cement production in 2005.

To implement this NAMA, the Federal government will need to work with the state and municipal governments, as well as the cement companies that own the local plants, in the design of municipal programs for the integrated management of solid and special wastes (PMPGIRSUME). This may also require that SEMARNAT modify existing standards for waste disposal (such as NOM-083-SEMARNAT-2003) or create new standards. The program would include all partners necessary for its fulfillment, and the costs would be spread among them. In other words, both state and private sector participation are required. The public-private-partnership (PPP) would perform a diagnosis of waste availability and quality. The additional services provided would include collection, transportation, treatment (e.g. separation and crushing) and final disposal of the associated wastes. Services would vary by municipality depending upon the current state of their waste management plans and the division of labor within the PPP.

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[4] See http://www.nuhcimento.com.tr/en/home/cevre.asp.

The cost of the proposed NAMA depends upon a number of factors:

- the number of waste processing facilities and tire shredders required (probably one each per municipality with capital costs of about $20 million and $500,000, respectively);
- the number of cement plants that need infrastructure or retrofits to store and use the alternative fuels (estimated to cost about $10 million per facility);
- transportation of the waste and/or alternative fuel;
- revenues or costs associated with the pricing scheme devised for the alternative fuel and the price of the displaced fossil fuel; and
- operation and maintenance of new facilities and equipment.

Therefore, the costs of the NAMA would vary depending upon the number of municipalities and cement plants involved, as well as the services already in place at each participating municipality and cement plant. It is likely that Mexico would attempt to achieve the proposed targets for alternative fuel use by minimizing the number of locations at which new facilities are required. Capital costs would be site-specific, depending upon the volume, composition, and location of the MSW stream, so participating municipalities would require an assessment of their existing and future management plans to determine the incremental costs of the proposed alternative fuels measure.

International Support

International financial support for the use of alternative fuels would be directed to providing a share of the resources needed to cover capital costs for the MSW treatment facilities and tire shredders, but the parties involved in implementing this NAMA (international financiers, the Mexican Federal government, municipalities, and cement companies) would need to agree how to distribute these capital costs among themselves and which of the two implementation scenarios described is optimal.

International assistance could come as a loan or grant for municipalities or cement companies, depending upon the contractual arrangements and whether alternative fuel use has a net positive or negative cost. However, assistance details, along with cost allocation, will be dependent upon the agreements resulting from the private-public-partnership and the final design of the NAMA agreed with the international donor. If all parties find the arrangement beneficial, it is less likely that either would push for a renegotiation of the concession contract with each new administration and thus more likely that a long-term supply stream of alternative fuels would be provided to nearby cement plants.

It is worth noting again that there would need to be strong coordination with the Mexican government to assess the level of effort backed with foreign resources to ensure achieving both targets.

Mexico: A Draft Iron and Steel NAMA[5]

The Copenhagen Accord calls on developing countries to undertake nationally appropriate mitigation actions, or NAMAs, in return for technological and capacity support as well as financing from developed countries. For a given industry sector, development and implementation of NAMAs offers an opportunity for international funding to support a lower carbon growth path. Developed countries are expected to steer funds to NAMAs that represent a clear and substantial reduction from business-as-usual emissions without changing the international competitiveness landscape. The challenge for the Mexican iron and steel industry is to develop NAMAs that are attractive to the international community while maintaining a competitive and expanding domestic industry.

The recommended NAMAs described below permit ongoing growth in the Mexican iron and steel industry while resulting in very significant improvements in the emissions profile for new and existing facilities. To address the unique needs and opportunities for new and for existing plants, we describe below two separate NAMAs that combine unilateral and supported actions and could seek international financial support. In addition, the recommended iron and steel sector NAMAs lend themselves to future development of credit-generating NAMAs, where offsets are produced for sale in the global carbon market. This would require developing estimates of the expected emissions reductions from the proposed NAMAs and procedures to credit emissions reductions that go beyond those estimates.

New facilities, because of the high growth projections for the industry, offer very significant opportunities to limit emissions. The potential emissions reductions come from enhancing the role of lower-emitting and state-of-the-art natural gas-based (NG) direct reduced iron (DRI) plants, implementing state-of-the-art blast furnace (BF)-basic oxygen furnace (BOF) plants coupled with carbon capture and storage (CCS) and/or emissions offset projects, and constructing state-of-the-art scrap-based electric arc furnace (EAF) operations. A main barrier to enhancing emissions reductions from new facilities involves questions about the future availability and costs of natural gas relative to coal. While stakeholders report excess import capacity through pipelines from the United States, current projections show natural gas demand exceeding existing pipeline capacity by 2019, assuming LNG imports remain constant. New pipeline capacity would be needed to fully take advantage of the expanded shale gas resource in the United States. At the same time, it is not clear that Mexico has sufficient coal production capacity and reserves to fully support future iron and steel production with domestic resources.[6]

[5] This report is made possible by the generous support of the American people through the United States Agency for International Development (USAID). The contents are the responsibility of the Center for Clean Air Policy and do not necessarily reflects the views of USAID or the United States Government.

[6] A paper by Dr. Robert-Bruce Wallace, a professor of economics in the Facultad de Economía, Universidad Nacional Autónoma de México, reports that, as recently as 2007, AHMSA only fulfilled 87% of its own requirements of metallurgical coal and complemented its needs with foreign imports. Further, while higher prices in August, 2008 resulted in increased production of coking (metallurgical) coal, this increase still only met most of AHMSA's growing needs. Continued growth in blast furnace

Mitigation options in existing facilities are highly differentiated, depending on the particular configuration and operational procedures of each plant, and are not known in great detail. The recommended approach to existing facilities is therefore based on an initial step involving facility-level energy and emissions audits.

A NAMA for Construction of New Iron and Steel Facilities

The high iron and steel production growth in the BAU projections for 2020 indicates that a large amount (18.5 mt) of new capacity will need to be built in the coming decade. This capacity will no doubt be more energy efficient and less carbon intensive than existing capacity, but further emission reductions can be obtained by ensuring that:

- a large amount of the new capacity uses the scrap-EAF route, within scrap availability, electricity availability and price, and finished steel product markets constraints,
- a large amount of the new capacity uses the DRI-EAF route, within natural gas and electricity availability and price constraints,
- any new BF-BOF capacity is coupled with verified emissions reductions from outside the iron and steel sector and/or includes measures to capture and permanently sequester greenhouse gas emissions,
- the new capacity is well equipped, encompassing all economically-viable mitigation options of the chosen processing route, and that
- plants remain well-run and well-maintained, through attention to housekeeping, maintenance, process scheduling, and process optimization.

We therefore recommend that a NAMA for new iron and steel facilities be comprised of the following elements:

A. All new steelmaking facilities, on which construction begins after July 1, 2011, would be required to meet carbon intensity performance standards, defined in terms of X tons of CO_2 / ton of Crude Steel. There would be separate standards for ore-based facilities (less than 50% scrap) and scrap-based (more than 50% scrap).[7] Facilities with emissions exceeding these levels could meet the respective standards by undertaking emissions reduction (e.g. wind farms) or sink enhancing (e.g. improved forest management) projects through a domestic offset program (see part E below). The final values of X would be negotiated between CANACERO and the Mexican government (SEMARNAT), but are envisaged to be about 1.3 tCO_2 / tCrude Steel, equivalent to the rate of a state-of-the-art natural gas-based DRI-EAF facility, for ore-based facilities, and 0.55 tCO_2 / tCrude Steel,

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production as projected by the Mexican iron and steel industry could continue to outweigh growth in metallurgical coal production.

[7] Definitions of ore-based and scrap-based plants would be negotiated between CANACERO and the Mexican government (SEMARNAT),

the rate of a state-of-the-art scrap-EAF facility, for scrap-based facilities.[8] The values of X would be based on the World Steel Association emissions data collection and calculation methodology (including direct emissions, energy-related upstream emissions, and possibly other upstream emissions and credits), and would be differentiated to account for non-integrated ironmaking plants and differing rolling and finishing operations. There would be secondary minimum performance standards specific to each of the BF-BOF, DRI-EAF, and scrap-EAF production routes to ensure that Mexico's iron and steel industry progresses on a best practice path, and to ensure that offset provisions are not overused.

B. Limited-term government subsidies, reflecting the carbon value of meeting the minimum performance standards instead of the business-as-usual emission rate, would be offered to all new ore-based and scrap-based facilities on which construction begins after July 1, 2011. As with the performance standards, the final values of the subsidies would be negotiated between CANACERO and the Mexican government (SEMARNAT), but are envisaged to be about €5 per ton of crude steel for BF-BOF facilities, €4 per ton of crude steel for DRI-EAF facilities[9], and €2 per ton of crude steel for scrap-based facilities.[10] The subsidy rates would be based on the carbon value (nominally €20 per ton CO2e) of the difference in emissions rates between average new (near best-practice) facilities and the minimum carbon intensity performance standard, differentiated by BF-BOF, DRI-EAF and scrap-EAF routes. For each plant, the carbon-value subsidy would be applied for the first five years of operation of the plant, then phased out over a second five-year period. Facilities would be allowed to come into the program if operation begins between 2011 and 2020. Foreign financial support would be used to cover subsidies.

C. The government would ensure the ability of iron and steel plants to enter into long-term contracts for NG. Facilities require the flexibility to make domestic or international purchases of NG at market rates.

D. CANACERO would implement a demonstration-sized CCS facility, partially financed with international funds, at one of its associate's plants.

E. Establishment of a new government program for qualifying and awarding offsets. This could involve accepting credits earned under the CDM, particularly those earned in Mexico. Emissions reductions achieved through a domestic offset program (including perhaps wind farms and improved forest management) could also potentially qualify. However, the government would need to administer a domestic offset program carefully to ensure continued international support for mitigation activities in the iron and steel sector.

A NAMA for Operating Iron and Steel Facilities

[8] These figures are presented for illustration purposes only. They need further refinement, in consultation with CANACERO and steel experts.

[9] This is roughly equivalent to €13.6 per thousand cubic meters of natural gas.

[10] These figures are presented for illustration purposes only. They need further refinement, in consultation with CANACERO and steel experts.

For iron and steel plants already in operation, and those that will come into operation in the future, a different type of GHG mitigation program is needed. As noted above, very detailed information is needed regarding the equipment, processes, and operational constraints of existing facilities before precise mitigation opportunities and costs can be identified with certainty. Fortunately, Mexico has an existing program of environmental audits that can be extended to the area of GHG mitigation and could form the basis for a NAMA for operating iron and steel plants (as well as other industries).

We therefore recommend that a NAMA for existing and new operating iron and steel facilities be comprised of the following elements, to be refined by CANACERO as per telephone conversation of Sept. 28, 2010:

A. A government requirement that all plants in operation implement energy and emissions management systems, with benchmark-ready data collection and reporting systems. Include provisions for instrumentation improvements, education and training, and certification and validation/verification systems. This is necessary to encourage continuous improvement and to prepare for eventual government programs to mitigate GHG emissions.

B. A government requirement that all plants in operation complete energy and carbon intensity audits every two years. The audit would include an assessment of technically viable mitigation actions, including the estimated implementation costs and emissions reductions from those actions. The audit would also include a unilateral Plan of Action for the facility to reduce GHG emissions. This Plan would at a minimum comprise all actions that together could meet a "break even" hurdle rate within a 5-year period. For new plants, on which construction begins after July 1, 2011, the first audit would be required only within four years. The companies would pay for the audits themselves, perhaps with a partial subsidy from international public support in some cases. The auditors would be certified by the Mexican accreditation agency, EMA, and approved by the government.

C. The government would receive copies of the audit reports and would approve the Plan of Action to be undertaken by the facility. The government would require that all mitigation options identified in the audit that together achieve a "break even" financial result within a 5-year period be implemented within 2 years after approval of the audit. Companies would pay for these improvements themselves, although smaller-size companies might qualify for a partial subsidy from international public support.

D. International public support would be employed to build the capacity in Mexico to implement this program, including training for government staff, EMA, and auditors. International public support could also help finance mitigation measures that are not funded through unilateral Plans of Action.

Estimated Impact and Incentive Payment

The NAMAs proposed above are estimated to achieve emissions reductions on the order of 6 million metric tons in 2020 and 10 million metric tons in 2030. The largest cost is expected to be the subsidies for new facilities beginning construction between 2011 and 2020 to meet the new source carbon intensity performance standards. As proposed, these (undiscounted) costs are expected to range from about €5 million in 2011, to €54 million in 2020, and back down to €1 million in 2029.[11] These payment levels reflect projected growth trends in the industry and assume that facilities are compensated for the emissions difference (at €20 per ton) between the average new plant and the state-of-the-art plant of the same type. Other costs are expected to include capacity building for the Mexican government and auditors, assistance to small companies to pay for audits and implementation of mandated action plans, and incremental costs of carbon capture and sequestration at one facility. A substantial portion of these costs would be compensated by the international community.

[11] These figures reflect the proposal to pay the full incentive level for five years, and a declining incentive level over the next five years. If payments were instead made at a constant level each year for ten years assuming a discount rate of 10 percent, the payment would be about €42 million each year from 2011 to 2020.

I. A NAMA FOR MONITORING, VERIFICATION AND REPORTING

Mexico's Emissions Mitigation Goals

In its submission to the United Nations Framework Convention on Climate Change (UNFCCC) regarding the Copenhagen Accord, Mexico announced a national goal of reducing greenhouse gas (GHG) emissions to 30% below business-as-usual (BAU) levels by 2020, conditional on its receipt of sufficient international financial and technical support. Mexico's submission also noted that it had previously released its Special Program on Climate Change (PECC) which listed a series of mitigation actions that it intended to undertake that would reduce national GHG emissions by 51 million metric tons (Mt), relative to BAU, by 2012. The PECC had also announced a goal of reducing per capita emissions to 2.8 tons of CO_2e by 2050, equivalent to a reduction of total emissions to 50% of the 2000 level in that year.

The Purpose of this Study

Mexico's Ministry of Environment and Natural Resources (SEMARNAT) has requested USAID assistance to support Mexico's efforts to prepare a low-carbon development strategy through 2020 and 2030, along with associated policy instruments. USAID engaged Abt Associates to assist USAID in its Support for Economic Growth and Institutional Reform project, and specifically in the Global Business, Trade and Investment sector. Within the context of Mexico's emission mitigation goals and USAID project objectives, Abt Associates subcontracted the Center for Clean Air Policy (CCAP) to assist Mexico in establishing measurable, tractable emission mitigation goals for the next 10 to 20 years through work on:

- the evaluation of GHG mitigation options in two key industrial sectors, including sectoral approaches and Nationally Appropriate Mitigation Actions (NAMAs), and
- the assessment and improvement of industrial sector and national measurement, reporting, and verification (MRV) systems.

The purpose of this paper is to evaluate options for MRV systems for Mexico. It is a complement to two other papers being prepared by CCAP which focus on mitigation options in the cement and iron & steel sectors.

What is MRV?

In terms of GHG emissions, MRV refers to identification of either the quantity of total GHG emissions and/or emissions mitigation, communication of those quantities to regulators or other interested parties, and use of third parties to check on the accuracy of those measurements.

While many aspects of the measurement and reporting of emissions and emissions reductions are very similar, the key difference is that emissions reductions are measured with respect to some reference level of emissions, generally a business-as-usual (BAU) baseline or a benchmark of some kind. Thus, the design of an MRV system for emissions reductions involves an additional consideration that MRV of total emissions does not: What is the proper reference value against which emissions reductions will be measured? This can be a difficult determination, and future estimates of emissions reductions may be systematically biased by a poor choice of this reference level. An accurate emissions baseline will ensure that reported emissions reductions from mitigation actions genuinely reflect changes in behavior and not an overestimate of the reference level of emissions.

The appropriate degree of accuracy in measuring emissions themselves depends on the intended use of the system. For instance, a national emission inventory (which is required to be reported to the UNFCCC) may use low-cost methods of estimating emissions in a particular industrial sector. At the other extreme, highly detailed and specialized methodologies are needed to measure and verify emission reductions for individual projects under the Clean Development Mechanism (CDM) of the Kyoto Protocol, due to the use of these reductions as offsets by developed countries. MRV of emission reductions for an industrial sector as a whole is an intermediate case between the extremes of a national inventory and an offset-based methodology.

The CDM has also provided a few examples of "Programs of Activity," which provide MRV methodologies for bundles of numerous smaller projects of a similar type. In addition, international funding mechanisms, such as the Global Environment Facility (GEF), which is a financing mechanism for the UNFCCC and other international agreements, have developed procedures to assess the performance of their projects and programs which are also of some relevance for the MRV of emission reductions. These can each provide lessons for a country wishing to MRV the GHG impacts of its NAMAs.

However, offset credits granted on a sector-wide basis, though widely discussed in principle, are not yet a feature of an international framework or of an existing emissions trading system (ETS). Therefore, new types of MRV methodologies for emission reductions need to be developed, perhaps drawing upon previous experiences with national inventories, CDM, and international funding procedures. Sector credits would presumably be granted based on verified actual emissions relative to a particular baseline for crediting. The methodologies used for such crediting would need to be robust enough to reassure buyers that the offset credits represent real, permanent, and additional emission reductions. Indeed, confidence in the accuracy of measurement and in the verification procedures will likely be essential to promoting the development of markets for sectoral offset credits.

II. Existing MRV in Mexico

Mexico has advanced farther than most other developing countries in measuring GHG emissions on a national level and also by individual enterprises and facilities. A number of government agencies and private sector institutions have been working on these programs for some years now. In addition, on a voluntary basis, many private sector companies in Mexico pay to have environmental audits of their facilities (although these do not currently included GHGs) and some make public reports on their GHG emission reduction activities. Thus, Mexico has lessons and experiences regarding MRV that it could usefully share with other developing countries. Nevertheless, considerable improvements are still possible. Government agencies tend to be understaffed and their technical capacities could be enhanced. Additional work is needed to standardize reporting methodologies and strengthen enforcement activities. Further private sector development also needs to be promoted; for instance, only a handful of energy saving companies (ESCOs) has been established as yet. This section discusses Mexico's existing MRV programs and the areas where improvements might be possible. Any or all of the agencies and bodies discussed here should be consulted when designing a unified system for the MRV of GHG emissions and emissions reductions for Mexico.

<u>Measurement and Reporting Programs</u>

Mexico's National Communications to the UNFCCC

Mexico has completed four National Communications to the UNFCCC, more than any other developing country. These "NatComs" include national emissions inventories as well as mitigation actions, among other subject matters. Mexico's National Institute for Ecology (INE), a government research institution associated with SEMARNAT, is responsible for completing the National Inventories. The overall responsibility for NatComs lies with Mexico's Inter-Ministerial Commission on Climate Change, which includes representatives of eight national government ministries. The GEF has provided funding to enable INE to hire consultants with expertise in particular economic sectors to complete the inventories.

INE conducts its work largely as a top-down effort. It does not make use of GHG emission data collected from individual firms or facilities under other programs, such as the RETC and GEI programs discussed below. Rather, INE generally estimates emissions using data on the outputs of various economic sectors, applying global default emission factors from the Intergovernmental Panel on Climate Change (IPCC). This is a "tier 1" methodology. The quality and availability of data limit INE's ability to use more advanced estimation techniques.

For example, Mexico's third NatCom makes a reference to the cement industry as an example where improvements are needed in estimating emissions. The report states that "there is no data available on clinker production in this country or on the CaO content of the clinker" (INE, 2007, pg. 61). The IPCC indicates that, if clinker production data are not available, a tier 1 method can be used to estimate emissions. This involves multiplying the production of cement times the clinker fraction of that cement type. In addition, to achieve "good practice," even for tier 1, a correction must be made for the country's overall imports and exports of clinker during the year (so that exports are included in emissions, while imports are not). Then, a default emission factor can be used for the estimated clinker production in the country.

To achieve tier 2 measurement level, clinker production must be directly measured (not estimated as above). In addition, it is good practice to estimate a country-specific emission factor for clinker. The IPCC default factor assumes that the CaO content of clinker is 65%, implying a particular quantity of CO_2 released from the limestone ($CaCO_3$) input. However, the CaO content of clinker tends to vary from 60% to 67%. In addition, tier 2 measurement requires an estimate of the production of cement kiln dust (CKD), small particles of clinker material that is not recycled within the kiln and therefore has emissions not included in the clinker output.

INE has been able to use an IPCC tier 2 method to estimate emissions in the iron and steel industry. A tier 1 method merely multiplies a default emission factor times the various types of output, including coke, sinter, direct-reduced iron (DRI), and liquid steel. The tier 2 method requires measuring the inputs and outputs used in the production of each of these products (default factors may be used for the carbon content of the inputs and outputs). CO_2 emissions are then measured as the net loss of carbon during the production activities over the year. This "mass-balance approach" is an improvement over the tier 1 method in that actual inputs are incorporated rather than assumed.

Tier 2 methods are also used to estimate Mexico's emissions of non-CO_2 gases in some cases.

Overall, INE is seeking to improve its data collection and to eventually develop national emission factors to replace some of the default factors used in its estimates of the national emission inventory.

Environmental Reporting in the RETC Program

Mexico’s Registro de Emisiones y Transferencia de Contaminantes (RETC) is a compulsory program for the reporting of air, water, soil and subsoil pollutants. It was established in 1994 as a pilot project through the United Nations Institute for Training and Research. It became law in Mexico on December 31, 2001, as Article 109bis of the General Law for Ecological Balance and Protection of the Environment. The RETC is administered by SEMARNAT.

The RETC includes only eleven economic sectors (petroleum & petrochemicals; chemicals; paints & inks; metals; automotive; pulp & paper; cement & lime; asbestos; glass; electricity; and hazardous waste treatment) because these are the sectors over which the Federal Government has jurisdiction. However, capacity is currently being built in States and municipalities that will allow them to institute similar programs for the sectors which they control. Mexican officials are also working with the Commission for

Environmental Cooperation (created through NAFTA) to develop consistent monitoring practices for regulated pollutants throughout North America.

For the RETC, each plant from a participating sector must submit an Annual Schedule of Operation (COA) that includes basic plant information (e.g., location, date on which operations commenced, hours of operation, number of employees, ownership details), amounts of fuel and electricity use, and a diagram of operations. The latter is a map of all activities and equipment at the plant that utilize inputs, consume water and/or fuel, emit any of 104 contaminants, generate hazardous waste, release waste water, liberate energy, and/or partially or totally transfer hazardous waste, solid waste or waste water. The list of 104 contaminants includes GHGs, and the quantity of emissions of each must be specified at any point in the diagram of operations at which such emissions occur (subject to a minimum emissions threshold). The purpose of this diagram is not to illustrate the steps in the production process from raw materials to finished products but instead to identify points at which contaminants are generated and/or emitted, as well as those places in which their production or release could be prevented or controlled.

The RETC program does not require firms to describe in detail the methodology they use to quantify emissions. A firm only needs to specify in general terms the type of methodology used – monitoring or direct measurement; materials balance; emissions factors; historical data; engineering calculations; mathematical modeling; or other. However, firms are required to provide their specific calculations to SEMARNAT or PROFEPA upon request. In addition, reporting of process emissions is optional. GHG emissions reporting under the RETC program is not subject to verification. The limited amount of government staff working on the program have so far focused their efforts on helping companies improve their emissions reporting.

In the future, however, greater emphasis will be placed on compliance, including possible prosecution of firms if their emissions reports have gross inaccuracies. Nevertheless, a more formal requirement for verification of reports of GHG emissions will be needed if GHG is to become subject to domestic regulatory controls or if the reports under the RETC program will be used for international MRV of supported NAMAs or sectoral NAMA crediting approaches, as discussed in later sections of this report.

Mexico's Voluntary GHG Program (Programa GEI)

In 2004, a program of voluntary reporting of GHG emissions and emission reductions by industry was initiated (Programa Gases Efecto Invernadero or Programa GEI; see www.geimexico.org/). Under a memorandum of understanding with SEMARNAT, Programa GEI is administered by the trade association CESPEDES, the Mexican arm of the World Business Council for Sustainable Development (WBCSD). Support is also provided by the WBCSD and the World Resources Institute (WRI), with some additional funding from the UK and from U.S. aid programs.

The objective of Programa GEI is to help companies develop the capacity to: (1) prepare corporate inventories of GHG emissions and (2) develop and quantify GHG emissions reduction projects. The methodologies and protocols used by Programa GEI are those developed by the WBCSD and WRI under their Greenhouse Gas Protocol (see www.ghgprotocol.org/).

The corporate reports under this program are designed to be made public on the GEI website. Data are generally provided at the corporate level, not at the facility level as under the RETC program. The format for reports is not standardized, but they are intended to include information on emissions and emission reduction projects. A corporation is expected to report annual estimates of its (1) direct GHG emissions from the combustion of fuels, as well as from industrial processes, and (2) indirect emissions from electricity use (Scopes 1 and 2, respectively, of the protocols for corporate reporting of the WBCSD). Other indirect emissions (scope 3), such as those associated with waste disposal or with transportation by vehicles that are not owned by the reporting company, may also be estimated. In some cases, companies provide estimates at the plant level, in addition to their aggregate emissions. The reports also indicate the operational locations of the company and the emitting sources and gases. Separate estimates may be provided for any of the six Kyoto gases (CO_2, CH_4, N_2O, HFCs, PFCs, and SF_6).

The corporate reports can also include information on emission reduction projects. In these cases, descriptions are provided of the location and boundary of each project, the baseline emissions, the estimated annual emission reductions, and the monitoring plan.

To date, industrial firms have been the primary participants in Programa GEI. In 2005, about 30 of Mexico's major companies prepared voluntary reports under the program, and the total emission reporting was about 89 $MtCO_2e$, representing about one-third of the industrial emissions reported in Mexico's annual inventory for that year. In 2009, 84 firms prepared emissions inventories and recorded 140 $MtCO_2e$ of GHG emissions, of which 80 $MtCO_2e$ came from the petroleum industry, 55 $MtCO_2e$ originated in other industrial sectors, and the remainder came from non-industrial companies.

In addition, Programa GEI has recently introduced its own certification program, with three levels of achievement:

- Level 1: a company is registered and provides an emission inventory;
- Level 2: a company obtains an external verification of its emission inventory; and
- Level 3: a company shows demonstrated reductions in emissions.

The SEMARNAT staff that administer the program are still developing the specific criteria that a company must meet to qualify for Levels 2 and 3, but they estimate that seven companies would have achieved Level 3 certification last year, if the program had been in place.

Mexico is actively promoting the growth of this program. In fact, the PECC expressed a number of goals for the GEI Mexico program for the 2008-2012 period. Specific targets include:

- Incorporating 50 new companies, agencies and institutions as well as four new economic sectors into the program, including the national electric utility, CFE (Comisión Federal de Electricidad);

- Covering 80% of national GHG emissions from energy generation and industry;
- Identifying and implementing 100 emissions-reduction projects that could be eligible for trading in a voluntary domestic carbon market, the CDM, or other carbon markets, along with systems for validating and certifying emissions; and
- Developing five studies that identify best practices, technologies and guidelines for emission reductions in a sector.

PROFEPA

Procuraduría Federal de Protección al Ambiente (PROFEPA) is the legal enforcement arm of SEMARNAT. It was established in 1992 and monitors compliance with environmental regulations related to pollution of the air, water, soil and subsoil; hazardous materials; and hazardous waste management. It has two basic functions:

- Inspection of industrial and service facilities that are under Federal jurisdiction to ensure and enforce compliance with Federal environmental regulations: mandatory standards (NOMs), voluntary standards (NMXs), and other regulations; and
- Management of a program of voluntary environmental audits.

The scheduling and frequency of compliance inspections by PROFEPA depends upon three considerations:

- A list of "priority" sectors based upon factors such as size of the facility, types of materials used in production activities, and by-products (e.g., emissions) generated;
- Complaints received; and
- Performance of high-risk activities.

The priority sectors for inspections are listed in Table 1 and include all of the sectors that must report emissions as part of the RETC program. There are currently 39,342 sources in Mexico that are subject to inspection, of which 5,843 emit atmospheric pollutants; 29,400 produce hazardous waste; 1,704 are involved in some form of hazardous waste management activities; and 784 perform various high-risk activities. [12]

At this time, Mexico has no national standards (NOMs) for GHG emissions, so these are not part of the PROFEPA inspection procedure.

PROFEPA's voluntary program of environmental audits, which also began in 1992, has been quite successful. These audits are more comprehensive than the compliance inspections, in that they examine the entire scope of operations of a facility and also include compliance with environmental regulations at the State and Municipal level. Even though the program is voluntary, and a company has to pay for the audit and any

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[12] PROFEPA website consulted on July 20, 2010 (http://www.profepa.gob.mx/PROFEPA/InspeccionIndustrial/LaInspeccionIndustrial/).

corrective measures, there are a variety of reasons that companies are interested in this program:

- Identification of cost-saving opportunities (e.g., reductions in water, energy and electricity use);
- Assistance in determining how to achieve compliance with environmental NOMs;
- Improvements in the environmental image of the company; and
- No PROFEPA compliance inspections occur during audits.

Table 1. List of Priority Sectors for PROFEPA Inspections

1	Basic Petrochemicals	17	Metalworking
2	Oil	18	Electrical and Electronic Components
3	Chemicals	19	Balers , coolers and soft drinks
4	Natural gas	20	Tanneries
5	Hazardous waste management	21	Hospitals
6	Metals	22	Mining
7	Electricity	23	Printing and printing houses
8	Paints and inks	24	Clinics and laboratories
9	Treatment plants using chlorine gas concession	25	Food
10	Mineral spirits and alcoholic beverages	26	Textiles
11	Glass	27	Mechanical Workshops
12	Cement	28	Plastics
13	Lime	29	Transport and freight service
14	Automotive	30	Wood products and furniture
15	Asbestos	31	Clay and ceramics
16	Pulp and paper	32	Other economic generators of hazardous waste

The audit process involves nine steps:

1. The company chooses an entity to perform the audit. These auditors must be accredited by Mexico's accreditation association (EMA), discussed below.
2. The auditor performs a preliminary scoping of the facility and develops a plan for the audit.
3. The audit plan is submitted to PROFEPA.
4. PROFEPA reviews and revises the audit plan, as needed, before authorizing the audit.
5. The audit takes place, typically lasting from three days to one month.
6. A report of the audit is prepared by the auditor. This is generally the longest step in the process (other than completing the Plan of Action described below) and can take up to six months.

7. A Plan of Action is developed to address any environmental deficiencies recorded in the audit.
8. The company makes a commitment to implement the Plan of Action.
9. Once the Plan of Action has been completed, PROFEPA issues a certificate to the facility that is valid for two years. In the industrial sector, these are called Clean Industry – "Industria Limpia" – Certificates. Certificates are also available for commercial and tourism establishments.

As of July 2010, voluntary environmental audits had been performed on 6,800 facilities, representing 70% of industrial GDP in Mexico. Of these, 2,131 have been certified, while the others are in the process of completing their Plans of Action. PROFEPA officials have estimated that for each peso spent by the Federal Government on the National Program of Environmental Audits, the benefit to society is about 109 Mexican pesos.

CONUEE

The National Commission for Energy Efficiency (CONUEE) is an administrative agency of the Ministry of Energy (SENER). CONUEE was created in November 2008 as the successor institution to the National Commission for Energy Saving (CONAE), which was established in 1989. CONUEE's responsibilities include registering major energy users, verifying that sustainable energy laws and regulations are being followed, developing methodologies to quantify energy use and GHG emissions, and generally promoting sustainable use of energy (for more details, see www.conae.gob.mx).

Federal agencies (including CFE and PEMEX, the national oil company) and energy intensive industries are required to report the following information to CONUEE: production, exports, imports, energy consumption by type of fuel, energy efficiency, and the implementation and outcomes of energy conservation measures.

CONUEE reported that there are only about eight private sector ESCOs operating in Mexico. The agency is considering employing these firms to verify sustainable energy use in Federal agencies and energy intensive industries that report to CONUEE. CONUEE has also developed a program of special recognition of institutions that are following best practices in energy use.

In addition, CONUEE was legally required to produce a report on methodologies for quantifying GHG emissions associated with the exploitation, production, distribution, transformation and consumption of energy and for reductions in GHG emissions associated with sustainable use of energy (CONUEE, 2009). It is not clear whether these methodologies will modify any existing practices under the RETC and GEI programs, but they are supposedly required to be used by all parts of the Federal Public Administration.

FIDE

The Trust Fund for Electrical Energy or Fideicomiso de Ahorro de Energía Eléctrica (FIDE) was created in 1990 as a parallel institution to CONAE to promote efficiency in the use of electricity. FIDE has helped implement demand-side-management programs with CFE, including a program for distribution of compact florescent lightbulbs (CFLs). To facilitate this program, FIDE sells the CFLs through CFE offices and uses CFE's billing system to collect reimbursements over time. FIDE's experience with electricity efficiency programs could guide the development of the related component of MRV, since energy efficiency is expected to be a large component of Mexico's mitigation effort.

Verification Programs

Mexico's Accreditation Association (EMA)

Entidad Mexicana de Acreditación (EMA) was created in 1999 as a private association with legal foundations in the Federal Law on Meteorology and Standardization. EMA was created in part to achieve international recognition of standardized products in Mexico for the purpose of reducing technical barriers to trade. EMA earns income through fees from the companies it certifies. EMA has achieved recognition as an accrediting organization from two international and three regional conformity assessment bodies.[13]

EMA began certifying environmental auditors in 2001, including those used by PROFEPA for mandatory inspections and for voluntary environmental audits. These auditors are private individuals or firms with expertise in particular areas. By the summer of 2010, EMA had certified 98 firms as environmental auditors in differing areas of specialization. These firms included a total of 372 qualified technical specialists.

EMA recently initiated a program to accredit verifiers of GHG emissions reduction projects. Its accreditations in this area are based on the international standard, ISO 14065:2007, *Greenhouse gases – Requirements for greenhouse gas validation and verification bodies for use in accreditation or other forms of recognition*. One key objective of this program is to develop a capacity within Mexico to perform verification of CDM or other carbon market projects.

EMA recently conducted a training workshop for those interested in becoming GHG verifiers; 36 people attended. These auditors will be qualified to evaluate emissions reduction methodologies and their application. They will not, however, be accredited to develop methodologies for establishing business-as-usual emission baselines. Potentially, these auditors could also verify GHG emissions reporting under the RETC and GEI programs.

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[13] The International Accreditation Forum, the International Laboratories Accreditation Cooperation Pacific Accreditation Cooperation, the Asia-Pacific Accreditation Laboratories Cooperation, and the Inter-American Accreditation Cooperation.

EMA's program to accredit auditors and verifiers of GHG emissions and emission reductions could potentially be expanded beyond facility, company, and project-level activities. For example, such auditors could potentially be employed to verify emission reports under the RETC program, other domestic programs to regulate GHG, and international frameworks for MRV of emission reductions. As discussed below, the Copenhagen Accord and the Cancun Agreements call for domestic verification of NAMAs that are undertaken by a developing country using only its own resources (a "unilateral" NAMA). EMA, and GHG auditors accredited by EMA, could be the agencies responsible for that domestic verification process. Moreover, because of EMA's adherence to international standards, its auditors could also be involved in the verification of NAMAs undertaken with international support. Finally, if sectoral programs are developed that are eligible to earn international offset credits, EMA and its auditors could play a role there as well.

Concluding Comment on Mexico's MRV Programs

While there are many areas in which Mexico's MRV activities could be improved, its domestic initiatives in these areas could point the way forward for some other developing countries. Mexico has taken important steps to update its national emission inventories, to mandate reports from public and private companies on GHG emissions, to encourage voluntary reporting of emission reduction activities, to enforce environmental regulations, and to develop a domestic capacity for verification of emission reports that corresponds to international standards. Because of the MRV institutions that Mexico has developed, and assuming that they continue to improve and expand on their missions, the country is well-positioned to take a leadership role in emerging international MRV systems, including possibly the domestic and international verification of NAMAs and sector offset crediting.

III. MRV in International Frameworks

UNFCCC/IPCC Guidelines for National Emission Inventories

The UNFCCC specifies in some detail the requirements for national emission inventories of developed countries (Annex 1 countries, per the Convention). In 1996, the Intergovernmental Panel on Climate Change (IPCC) produced detailed guidelines for the reporting of national emission inventories by Annex 1 countries. Those guidelines have been revised over time and supplemented by "Good Practice" guidance. In 2006, the IPCC issued a revised set of guidelines that incorporated all previous revisions and the good practice guidance (IPCC, 2006). However, the 2006 guidelines have not yet been accepted as the updated standard required for Annex 1 (A1) country inventories.

The IPCC lays out three tiers of reporting procedures. Tier 1 is based on national-level production data and the use of generic emissions factors (e.g., ton CO_2 per ton product). As mentioned previously, Tier 2 incorporates country-specific emission factors for fuel combustion and, for process emissions, involves a mass-balance approach that uses national-level reports on production inputs and outputs along with use of default carbon contents. Tier 3 involves detailed emission models or facility-level data on inputs and outputs, emissions factors and carbon contents. Alternatively, tier 3 may involve direct measurements of emissions at a facility.

Tier 1 is generally not to be used for “key source categories.” Key source categories are those with the highest levels of emissions in a country and which cumulatively amount to at least 95% of the country's emissions. (The IPCC specifies about 72 source categories that can be used in the identification of key categories – see IPCC, 2006, Volume 1, chapter 4.)

IPCC guidance also provides information on avoiding double counting of industrial emissions with those from the energy sector and provides procedures for quality assurance/quality control, reporting, and documentation.

Under the UNFCCC, emissions inventories of A1 countries are:

- Required once per year;
- Initially checked by the UNFCCC secretariat;
- Subject to a “desk review” by experts in various countries or a “centralized review” in a meeting of experts; and
- Subject to a thorough in-country review by a UNFCCC-appointed expert team every five years.

The annual and five-year expert review reports are available to the public. This is interpretable as a verification process – especially when combined with provisions from the Kyoto Protocol (see Fransen, 2009, and Breindenich & Bodansky, 2009).

On the other hand, the emission inventories of developing countries (DCs) are included in their National Communications (NatComs). The inventories require reporting on only 3

GHGs: CO_2, methane, and nitrous oxide. According to the Convention treaty, A1 countries provide financial support to help DCs cover the costs of preparing their NatComs. The initial NatCom is required within 3 years of receipt of the related financial assistance, while the second NatCom is required within 4 years of receipt of funding. Through December 2010, 140 DCs had submitted initial NatComs (with inventories for 1990 or 1994), 39 had submitted a second NatCom (with inventories for 2000), and two had submitted a third NatCom. Only Mexico has provided 4th NatCom.

The NatComs from individual DCs are not subject to review. However, expert teams and the UNFCCC's Subsidiary Body for Implementation have summarized groups of reports. They identified the need in DCs for better activity data, research on country-specific emission factors, and institution-building to develop continuous data flows rather than one-off inventory accounting.

UNFCCC Guidelines for Policies and Measures

In the absence of explicit guidance on MRV for NAMAs, a variety of existing sources could be consulted. The guidelines provided by the UNFCCC for reporting on policies and measures (PAMs) in A1 National Communications are one source (see UNFCCC, 1999). A1 countries are required to submit National Communications only every 4 years or so, as these NatComs do not include national inventories (which are reported under a separate format annually), but they do include PAMs. These PAMs can be undertaken at the national, state, provincial, regional, or local level, and are to be reported by sector and subdivided by GHG. The sectors are energy, transport, industry, agriculture, forestry, and waste management. The GHGs are CO_2, methane, nitrous oxide, HFCs, PFCs, and sulphur hexafluoride (which are also the six gases of the Kyoto Protocol). The effects of multiple PAMs in aggregate on a particular sector or GHG can also be provided.

A PAM is to be described within the context of national targets for GHG mitigation and sustainable development, keeping in mind the achievement of the longer-term GHG goals of the UNFCCC. Specific objectives for the PAM, preferably in quantitative terms, are to be given. The implementing entities and status of implementation are to be identified. A quantitative estimate of the impacts of the policy is required, including changes in activity levels, emissions or removals of GHGs. The institutions and methods used to monitor, estimate quantitative effects, and evaluate progress in GHG mitigation through the PAM are also to be described. In addition, information may be provided on the costs of the PAM, the co-benefits, and the interaction (or complementary effects) with other PAMs at the national level.

In addition, projections of the quantitative effects of PAMs in aggregate are required as a national total and for each sector and each GHG. Projections are also required for the effects on the indirect GHGs (air pollutants that can be chemically transformed into GHGs: carbon monoxide, nitrogen oxides, sulphur oxides, and volatile organic compounds other than methane). The projections should include a "without measures" (or BAU) forecast that starts in 1995 or another base year. The "with measures" forecast scenario should start with the year after the latest emission inventory and should include the years 2005, 2010, 2015, and 2020. Another, more ambitious "with additional measures" scenario can also be included. The effects of the PAMs would be the difference between the with- and without-measures projections. Projections can also be made of the effects of each PAM (and then summed to get the aggregate).

A1 countries are required to describe the models and approaches used to construct these forecasts. Key underlying assumptions should be reported, including GDP, population growth, tax levels, and international fuel prices. The Parties should describe the strengths and weaknesses of the models and approaches, the sensitivity of results to underlying assumptions, and the method of accounting for overlaps and synergies among the PAMs.

A1 NatComs are also subject to centralized or in-country reviews by panels of UNFCCC-approved experts. The review report is available to the public. However, the reviews cover only whether the country met the reporting guidelines. They are not a verification of emission results or a judgment on the level of effort of the country.

Could these PAM guidelines serve as a model for reporting on NAMAs in developing countries? This is not clear. In an overall review of A1 PAMS, the UNFCCC's Subsidiary Body for Scientific and Technical Advice (SBSTA, 2002) indicated that it was difficult to assess the additionality and therefore the cost-effectiveness of PAMs, especially in regards to industrial energy efficiency improvements. Private industries often had strong economic incentives to reduce energy use. Given also the complexity of GHG emission structures, the difficulty of monitoring, and competitive pressures, A1 governments have often relied on voluntary and cooperative programs for private industry. Nevertheless, energy efficiency improvements have reduced GHG combustion emissions and some process emissions as well (e.g., from increased blending in cement). Beyond energy efficiency, the most cost-effective options for GHG abatement in industry have involved non-CO_2 emissions. The SBSTA also commented that "traditional regulatory approaches that focus on individual processes or industrial sites … may create barriers to the multi-sectoral, innovative actions that are required for materials substitution," such as engineered wood for steel and fly ash for clinker.

<u>CDM Projects and Program of Activities</u>

The Clean Development Mechanism (CDM) projects and the Program of Activities model provide valuable insight to inform the design of MRV systems for NAMAs. The CDM project cycle includes design, validation, implementation, and verification. Program of Activities (PoAs) are intended to enable the bundling of small scale projects and thus help reduce financial costs and regulatory burdens. In a PoA, the private or public entity that coordinates and implements the associated policy is responsible for measuring the sub-program project activities (CPAs). Each CPA must produce direct, real, and measurable impacts on emissions reductions and generally follow project methodologies. The CPA may be geographically or temporally dispersed and include a large number of project owners.[14]

[14] A Primer of CDM Programme of Activities.

In a PoA, the proposed MRV procedures are submitted to a Designated Operational Entity (DOE) for validation. The DOEs are accredited by the CDM Executive Board (EB) and represent an independent third-party review of a project or program. The EB then decides whether to register ("approve") the PoA.

Verification generally involves a different DOE than the one which performed validation. First, the verifying DOE reviews the project documentation and monitoring results to ensure that the project design has been followed and the monitoring methodologies have been applied correctly. This DOE then verifies the emission reductions that have been achieved as additional reductions because of the project or program. The EB then issues certified emission reductions (CERs).

MRV of CDM PoAs involves the costs of completing the design document, the fees for DOE at validation, the fees for registration by the EB, and the additional DOE costs for verification. These costs would be significantly higher if each CPA within the PoA had to go through this process. One study estimated the total transaction costs for individual CDM projects to be between 19,000 Euros and 121,000 Euros.[15] Moreover, the projects risk never getting CERs approved. With a PoA, additionality is assessed all at once for all potential CPAs in the program and sampling procedures may be used for verification.

The CDM project cycle and the PoA MRV design both offer elements that can be considered for MRV of NAMAs. However, a PoA is designed for credit-generating activities, which will not be the case for unilateral and supported NAMAs. Nevertheless, the components of third-party validation of projects or programs and third-party verification of results could also be useful for NAMAs. Moreover, the CDM's practice of identifying monitoring and verification methodologies that are specific to each project and program could be followed.

<u>The Global Environment Facility (GEF)</u>

An alternative possible model for MRV of supported NAMAs is the monitoring and evaluation program of the Global Environment Facility (GEF). The GEF operates as the financial mechanism for several international treaties or conventions, including the UNFCCC.[16] Established by the World Bank in 1991, the GEF became an independent institution in 1994. The World Bank continues to provide administrative services as trustee to the GEF. The GEF provides funding through ten implementing organizations, including several multilateral development banks (MDBs) and various UN-affiliated development organizations. The GEF is governed by an assembly of the 182 participating countries (which meets every three or four years) and a more hands-on council of 32 representatives (half of which are developing countries).

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[15] Transaction Costs Under the Finnish CDM/JI Pilot Program. Ahonen, Hanna-Mari and Kari Hamekosky. 2005.

[16] The others are the Convention on Biological Diversity, the Stockholm Convention on Persistent Organic Pollutants, and the UN Convention to Combat Desertification.

The GEF's climate change programs include renewable energy (domestic, rural, and hot-water solar systems, pre-commercial and grid-connected), energy efficiency (buildings, products, and industry), and fuel-switching. The GEF has also been a channel for grants from Annex I countries to enable developing countries to complete their UNFCCC National Communications.

The GEF has an evaluation office that reports directly to the GEF Council; it thus operates independently from the secretariat staff. The GEF's scientific and technical advisory panel may also participate in making evaluations of GEF projects and programs (GEF, 2006). In addition, the implementing organizations share responsibility for monitoring and evaluation of projects and programs.

General MRV at GEF

Monitoring and Evaluation (M&E) at the GEF takes place on several levels:
1. Individual project level;
2. Program level (for a set of projects within the same focal area or targeting the same strategic priority);
3. Country-level (which can include the programs of one or more implementing agencies within a single country);
4. Cross-cutting and thematic level, evaluating all interventions that address a specific concern in multiple countries or regions; and
5. Overall performance of the GEF itself.

Project-level evaluations are undertaken by the implementing partner agencies (MDBs and UN development agencies) using their own norms and standards, though the GEF Council can prescribe minimum standards and procedures to be applied in these evaluations. At a minimum, all GEF project M&E plans must contain:
1. Performance indicators for project implementation that are Specific, Measurable, Achievable, Relevant & Realistic, and Time-bound (SMART);
2. A project baseline with selected indicator data (BAU often acts as the baseline);
3. Identification of reviews and evaluations that will be undertaken for the project; and
4. Organizational set-up and budgets for M&E.

Program level evaluations are undertaken by the GEF secretariat. These involve outcomes and impacts across specific focal areas, such as climate change.

The GEF Evaluation Office undertakes broader cross-cutting and thematic assessments in individual countries and across multiple countries as well. The Evaluation Office also bears responsibility for the M&E systems used by the implementing agencies. It conducts verification of project impacts as reported in the terminal evaluations submitted by implementing agencies. In the past, the verification process was less robust, consisting mainly of reviewing the terminal evaluation documents. But GEF performance assessments highlighted the need for more direct verification of completed projects to ensure the veracity of the submitted terminal evaluation reports. In response, the GEF Evaluation Office now conducts direct verifications of project impacts, including field visits, for projects with over US$ 1 million of GEF funding.

To fulfill its responsibility of monitoring GEF programs and portfolios (which include all implementing agency projects), the GEF secretariat requires implementing agencies to provide information on ongoing projects on a yearly basis. It uses this information to create an annual Project Implementation Review which is submitted to the GEF Council for oversight. The Secretariat is also responsible for developing the program-level indicators used in project M&E, with help from the implementing agencies and input from the GEF Scientific and Technical Advisory Panel (STAP).

GEF MRV of Climate Change Programs

Unlike the CDM, which focuses mainly on technical projects that result in direct emission reductions, the GEF seeks long-term, transformative effects on market development, removal of market barriers, and policymaking capacities. The GEF views these catalytic effects as important for achieving long-run emissions reductions. This requires an MRV methodology that: (1) takes account of outcomes beyond direct GHG emission reductions, and (2) considers the sustainability and replication potential of projects.

The GEF employs seven core performance indicators to evaluate the success of its climate mitigation projects:

1. Energy production or savings and installed capacities
2. Technology cost trajectories
3. Business and supporting services development
4. Financing availability and mechanisms
5. Policy development
6. Awareness and understanding of technologies
7. Energy consumption, fuel-use patterns, and impacts on end users

These indicators can be measured at both the project level and the country level, as they reflect both broader trends and specific impacts. Plausible linkages must be identified between GEF activities and changes at the national level. The GEF considers the linkages between project-level and national-level impacts to be the key factor that elevates the GEF to a programmatic entity, rather than just a funder of a collection of projects.

Recently, the GEF established GHG emissions as a performance indicator for climate change projects. However, its approach to MRV remains different from that of the CDM. Its starting baseline is the overall state of a market in a country, not just a BAU scenario for a single project. It also takes account of investments and other activities that occur after the implementation period of the project and that are attributable to the GEF intervention. In particular, the GEF measures three types of emissions reductions:

(1) Direct – savings directly attributable to investments made, totaled over the lifetime of the investment;
(2) Direct post-project – GHG reductions directly linked to financial mechanisms introduced by the project that continue to function beyond the implementation phase; and
(3) Indirect – GHG reductions achieved over the long term that are linked, in part, to the actions of a GEF project to remove barriers in the policy framework.

For calculating direct emissions savings, GEF implementing agencies utilize methodologies similar to those used to calculate the emission reductions in CDM projects. Estimating post-project emission reductions requires assumptions about how the GHG reduction-supporting mechanisms will continue after the project period. Indirect emissions estimates require further assumptions and expert judgment. For instance, they are weighted by a "GEF Causality Factor" – the estimated influence of the GEF project on achieving other reductions.

The GEF also uses a judgmental project scoring methodology, which involves qualitative assessments of performance relative to targets. The sustainability of the project impacts is also rated, based on an assessment of the risks that could cause a discontinuation of the benefits of the project, such as the availability of financial resources, the permanence of the institutional framework and governance in place, and environmental risks.

Implementing agencies must send all terminal evaluations to the GEF Evaluation Office for review and verification. That office uses the evaluations in its Annual Performance Report to the GEF Council.

Example of a GEF Project with NAMA-like Features

The GEF itself could serve as a channel of finance for some types of NAMAs, particularly those involving capacity building or smaller-scale programmatic approaches. An example is the first climate change "project" financed by the GEF, which involved the financing of solar-powered water pumps and other equipment in rural Mexico. Consistent with the priorities of the Mexican government, the objectives of the project were to:

- Promote the use of renewable energy for productive purposes in Mexico's agriculture sector by removing barriers and reducing implementation costs; and
- Reduce greenhouse gas emissions in the agriculture sector.

This was a nation-wide program implemented through local institutions. Investments were made in demonstration projects in 28 of Mexico’s 32 states. The project was designed to:

- Provide unelectrified farms with reliable electricity supply for productive purposes in a least-cost and sustainable manner using renewable energy technologies;
- Increase the productivity and income of unelectrified farms by supporting the adoption of productive investments and improved farming practices; and

- Provide capacity building to strengthen a Mexican agency's (FIRCO's) ability to catalyze use of renewable energy technologies in the agriculture sector.

Four key performance indicators were identified at the beginning of the project and were used to assess its achievements:

1. National sales of renewable energy systems for productive agricultural applications;
2. Change in average price of renewable systems;
3. Carbon emissions avoided by project-supported renewable energy systems; and
2. Change in average net income of participating farmers.

The World Bank/GEF terminal evaluation report (World Bank, 2007) assessed these key performance indicators and 18 intermediate outcome indicators such as the number of solar water pumps installed and operating correctly, the total technicians trained by state, and demonstration days held. For each indicator, the terminal evaluation includes a baseline value, the original target and the actual value achieved by the project.

For example, the target value of rural sales of solar power installations was a 50% to 80% increase in 2005, relative to 2000. Actual sale increases were much higher, reaching 700% by 2006. Direct GHG reductions were estimated to be over 36,000 tons of CO_2 by 2005, exceeding the target of 30,000 tons.

<u>The European Union's Emissions Trading System (EU ETS)</u>

Another potential model for MRV is the EU ETS, which requires each covered facility to submit a monitoring plan that describes how its GHG emissions will be calculated or measured. Calculation-based methodologies for GHG emissions monitoring are generally preferred over measurement-based systems. In fact, a company that would prefer to measure emissions directly must show that this will capture all of the same "emissions sources and source streams" as an equivalent calculation-based methodology.

The general equation that is suggested for the calculation of CO_2 emissions is:

$$CO_2 \text{ emissions} = \text{activity data} * \text{emission factor (EF)} * \text{oxidation factor (OF)}.$$

In the case of combustion emissions, the activity data are to be broken into two multiplicative factors: fuel flow and the net calorific value of the fuel.

Process emissions are quantified through:

$$CO_2 \text{ emissions} = \text{activity data} * \text{EF} * \text{conversion factor},$$

where activity data involve units of consumption of inputs, throughput, or production of outputs. The conversion factor is a fraction between zero and one; it accounts for the carbon that is retained in the materials rather than being converted into CO_2.

The EU ETS also specifies tiers for the precision of the factors that appear on the right-hand side of the above equations. Greater precision is generally required for higher-emitting classes of installations. For this reason installations covered by the EU ETS are divided into three categories, depending upon their "average reported annual emissions during the previous trading period (or a conservative estimate or projections if reported emissions are not available or no longer applicable)." Category A installations have emissions less than or equal to 50 thousand metric tons (kt) of fossil CO_2 emissions "before subtraction of transferred CO_2." Annual CO_2 emissions for Category B facilities lie between 50 kt and 500 kt, and Category C installations have more than 500 kt of CO_2 emissions per year.

For each tier of calculations of both combustion emissions and process emissions, specific guidelines are provided for several industries: mineral oil refineries; coke ovens; metal ore roasting and sintering; the manufacture of pig iron & steel, cement clinker, lime, glass, ceramics, and pulp & paper.

IV. MRV and Future International Mechanisms

Mexico's MRV Experience, the Copenhagen Accord, and the Cancun Agreements

MRV has been a central issue in the negotiation of an international framework to deal with climate change. The Copenhagen Accord specified that DCs would begin to provide NatComs every two years and that these NatComs would include information on unilateral and supported NAMAs. However, the Cancun Agreements modified the content and frequency of non-Annex I country NatComs such that these would "not be more onerous than that from for Parties included in Annex I to the Convention" (Annex I Parties currently produce NatComs every four years). The UNFCCC Conference of Parties (COP) is supposed to provide further guidelines for the content of these NatComs, and for biennial reports on NAMAs that would be subject to international consultation and analysis (ICA) with respect for international sovereignty. The details of the consultation procedure are not yet clear, but the setting will likely be the meetings of the Subsidiary Body for Implementation. Various proposals have been advanced for the content of the NatComs and the ICA process. Many commentators have advocated full NatComs for DCs only every 4 to 8 years, with streamlined updates every two years (see, e.g., Ellis, 2010). Procedures from the World Trade Organization review process could potentially be adapted for ICA.

Under the Copenhagen Accord, unilateral NAMAs would be subjected to domestic MRV. The COP could potentially provide guidance that could lead to some standardization of the domestic MRV process. The COP is also expected to provide guidelines for international MRV of supported NAMAs, which would initially be recorded in a registry and then again in Appendix II of the Copenhagen Accord after support is agreed.

Mexico's experience with its internationally recognized accrediting institution (EMA) and the environmental auditors accredited by EMA could be relevant to the international discussions of new MRV approaches. In particular, domestic verification of unilateral NAMAs could potentially involve domestic accrediting bodies and auditors in DCs. The international community might therefore look for ways to promote the establishment of accrediting bodies more widely among DCs and to support their work in accrediting and training auditors of GHG emissions and emission reductions.

As EMA's experience in Mexico has revealed, establishing accrediting bodies and certified auditors is not sufficient to ensure MRV of emissions and emission reductions. There is also a need for officially-approved methodologies for reporting on emissions, baselines, and emission reductions relative to those baselines. Auditors need to use such methodologies as the standards against which to verify emissions and emission reductions. To some extent, auditors themselves can be involved in assessing whether a "method" used to measure emissions or establish a baseline at a particular facility corresponds to standards or more general principles for such methods. However, methodologies with broad potential applicability across a range of projects (or NAMAs) would require a higher-level approval body. For example, without explicit guidance from an international body, an individual auditor (or DOE) would not be qualified to approve the baselines to be used for sector crediting. Indeed, in some cases, judgments regarding international MRV methodologies for sectoral and similar broad policy-based programs may involve political negotiation in addition to technical assessments.

Fast Start Finance

Under the Copenhagen Accord, developed countries agreed to provide $30 billion in financial support for developing country mitigation and adaptation actions between 2010 and 2012. During this "Fast Start" period, public finance from Annex I countries is being provided through existing bilateral and multi-lateral channels, including international bodies such as the GEF. It is unclear to what extent the existing MRV procedures for those financing channels will be adapted to take account of the increased financing of climate mitigation and adaptation.

Longer-term Finance

Under the Copenhagen Accord, A1 countries also agreed to mobilize, by 2020, $100 billion annually through a variety of public and private sources to finance mitigation and adaptation activities in DCs. Some of this financing would be channeled through a new financing mechanism for the UNFCCC, a Green Climate Fund (Green Fund).

The terms of reference for the design of the Green Climate Fund were specified as part of the Cancun Agreements, and a variety of options are possible for the design of this fund. One possibility is for the Green Fund to provide supplemental sources of financing that complement existing sources, somewhat along the lines of the GEF. Another would be to have the GEF continue to play that complementary financing role when smaller sources of funding are needed, while the Green Fund focuses on larger financings, perhaps filling gaps not covered by existing sources of funding. In addition, it has not yet been decided whether the Green Fund would provide “direct access” to developing countries (similar to the Adaptation Fund) or have some other structure for accessing funds.

Another option would be for the Green Fund to absorb and expand upon the role of the two Climate Investment Funds (CIFs): the Climate Technology Fund and the Strategic Climate Fund, both of which operate under the trusteeship of the World Bank. The Climate Technology Fund focuses on promoting investments that foster the demonstration, deployment and transfer of low-carbon technologies. The Strategic Climate Fund serves as an overarching fund that supports new transformational actions aimed at: (1) reducing emissions from deforestation and degradation, (2) integrating climate risk and resilience into core development planning, and (3) scaling up renewable energy in low income countries. The CIFs have channeled only a small amount of financing so far (only $6.3 billion had been pledged to them through 2009).

CIF investment decisions are made by the Trust Fund Committee, which is composed of an equal number of developing and developed country representatives with equal voting power. The World Bank and other multilateral development banks also sit in on the

Committee meetings, though without voting power. If the CIFs are absorbed into the Green Fund, the governance structure would likely change to reflect the overall authority of the COP and a greatly expanded scope of activities.

Future Offset Markets

At present, it is unclear whether the Kyoto Protocol will be extended to a second commitment period after 2012 or whether a new international treaty will be reached that includes new types of carbon market mechanisms. In the absence of a well-defined global framework, offset crediting could be continued as a function of the EU ETS and possible other new national or regional ETS.

The traditional project-based MRV systems of the CDM could be continued or modified for these purposes. Various types of streamlined mechanisms for the CDM remain under discussion that have implications for MRV systems (including standardized baselines for projects in given sectors, positive lists of projects that are automatically considered "additional", and negative lists of projects that will not be allowed).

New MRV procedures will be needed if some NAMAs will be eligible to earn international credits or if sector crediting approaches are to be implemented. For example, sector credits could potentially use baselines formulated in terms of the emission intensity of production. To implement such a system, the definition and boundaries of a sector need to be carefully specified and the benchmark to use as a baseline for crediting would need to be agreed upon. The appropriate boundary and baseline might differ from one country to the next. An entirely different approach to sector crediting, based on technology penetration goals (such as the share of a DC's power generation from renewables), could also potentially be employed.

V. MRV Components of a Possible Capacity-Building NAMA

Although Mexico's MRV systems are fairly well developed when compared with other DCs, a number of improvements are possible. International assistance could potentially play a role in helping Mexico build the capacity of its institutions, leverage their activities and refine their procedures. Indeed, even Annex I countries have found that their emission measurement and reporting capabilities are improved when their national inventory reports are reviewed by expert panels.

In Mexico, the RETC program, administered by SEMARNAT, already requires GHG emissions reporting in many economic sectors. However, the program covers all environmental pollutants, not just GHGs, and must be administered by a limited number of staff (even including the PROFEPA staff involved in enforcement). This constrains both the amount of training and assistance that government officials can give to reporting companies and the amount of analysis that can be conducted of the emissions data that the government does receive.

Voluntary reporting under the Programa GEI, administered jointly by SEMARNAT and the industry association CESPEDES, can also be given only a limited amount of review and analysis, given the staffing constraints. Further comparison and reconciliation of Programa GEI data with the RETC reports is a high priority. Ideally, government officials would have more time to discuss and review the reported data with the individual reporting companies in order to improve clarity and understanding about what has been reported and how it could be improved in the future.

Companies are already engaging the services of environmental auditors (under the PROFEPA program) to help assess the environmental effects of their activities. Although EMA has certified about 100 auditing firms with differing environmental specialties, it is only now beginning a program to certify auditors of GHG emissions and abatement.

CONUEE has already undertaken initial work on methodologies for GHG reporting, and both CONUEE and FIDE have played a role in fostering improvements in energy efficiency. The development of a private sector ESCO industry in Mexico is fairly limited as yet. Growing the capacity of these types of institutions would greatly facilitate Mexico's ability to MRV emissions related to energy efficiency.

International capacity-building assistance to the above institutions would help to accelerate progress in the achievement of their important missions. Such assistance could include the provision of international expertise to help these institutions directly in developing the GHG components of their MRV activities. Institution-building activities could also possibly include temporary placement of key staff from these institutions with foreign institutions engaged in comparable activities for training purposes. Funding could also be provided for these Mexican institutions to outsource to private consultants some aspects of an expanded scope for their mission, such as review and analysis of data on GHG emissions (while preserving confidentiality of individual company data), along with preparation of baseline forecasts and emission abatement scenarios in various economic sectors.

In addition, funding for capacity building could include support for enhanced coordination of GHG measurement and reporting activities within Mexico. At present, there are a variety of different GHG emission measurement methodologies that are used in Mexico. These include:

- A range of methodologies for facility- and process-based reporting that can be used in the RETC program;
- The WBCSD/WRI Protocols used for company-level reporting in Programa GEI;
- The procedures used by INE to prepare the national emissions inventories;
- The methodologies published by CONUEE to be used by Federal government entities; and
- Methodologies used for CDM projects and Programmes of Activity.

Some of these methodologies share common features. For instance, both INE and CONUEE employ aspects of IPCC emission reporting methodologies. However, the IPCC methodologies themselves include a variety of different possible approaches.

There are some advantages to using different methodologies for different purposes. For example, achieving precision in estimating emissions at the facility level is prohibitively expensive if the purpose is merely to estimate a sector's overall emissions for a national inventory.

However, there are disadvantages of having too many reporting methodologies simultaneously. Companies are then required to maintain different types of reporting systems and the reported data are difficult to compare. In light of these issues, Mexican officials themselves have expressed the desire to achieve greater harmonization among the GHG reporting methodologies used in the country. It may be possible to coordinate reporting methodologies to some degree so that companies can largely use the same reports to comply with domestic laws and regulations while also meeting the needs of future funders of NAMAs and international crediting programs.

In addition, additional work could be undertaken regarding the format for reporting on GHG emissions. The report form for the RETC program (the COA) is currently used for facility-level reporting on a wide range of pollutants (including GHGs). The GEI program does not have a standard format. Agreement on a standardized format for GHG reporting would be an important element in developing a future registry of GHG emissions in Mexico. Presumably, the COA could form the basis for a standardized report on GHG emissions, but it may need to be modified to some extent to focus on unique issues related to GHGs rather than general pollution reporting.

One aspect of a capacity-building NAMA could therefore be to facilitate the achievement of greater harmonization of methodologies and greater clarity in the differing reporting requirements regarding GHGs in Mexico. A series of meetings and workshops could be conducted that would bring together different government officials and, at a later stage, industry representatives. The purpose would be to establish a standardized system of measuring and reporting of GHG emissions. This would include the development of a registry of emissions. It would address the issues of emissions calculation methodologies and reporting formats, along with associated topics such as facility and sector boundaries and the use of default emissions factors. The workshops could initially include representatives of government agencies involved in GHG reporting (e.g., RETC, PROFEPA, INE, CONUEE, Programa GEI), then expand to involve other officials from affected ministries and agencies. In a subsequent step, other stakeholders would be brought into the dialogues, including public and private reporting companies and industry associations.

Capacity building could also strengthen and expand the important initiatives that Mexico has undertaken in the verification of emissions. These include the roles of PROFEPA, EMA, and environmental auditors. The GHG elements of these programs are currently being expanded and further developed. In addition to direct support of these institutions, further analysis could be undertaken with them on how to direct their future roles in ways that mesh well with emerging international structures (such as ICA). The extent of review, cross-checking, and follow-up on GHG reporting from companies could be expanded. In addition, analyses could be prepared on establishing baseline forecasts for various economic sectors in Mexico. Emission reduction efforts for the achievement of domestic goals and for the requirements for external funders of NAMAs could then be assessed relative to those baselines.

The results of this work would likely be included in Mexico's future National Communications, assuming the provisions of the Copenhagen Accord and the Cancun Agreements are to be implemented. Mexico's work in this area could also be an important input for the elaboration of broader guidelines for National Communications and MRV approaches to be developed by the COP as part of implementation of the Cancun Agreements. Thus, one of the purposes of further capacity building on MRV in Mexico could be to harvest lessons for future international guidelines to be used by developing countries more generally.

A Timeline for the MRV NAMA

Based upon the above considerations, CCAP proposes that the MRV NAMA for Mexico proceed in two phases. Phase I would be short-term, and we believe that it could be completed within six months. It would involve a series of monthly workshops, and the primary participants, at least initially, would be officials from various agencies that are responsible for GHG emissions reports or for data that could be used for review of emissions reporting. Relevant agencies include SENER, INEGI, SEMARNAT (e.g., RETC, Programa GEI, PROFEPA), INE, CONUEE, etc. It would also be beneficial to involve other officials, such as those from industry, in these workshops at some point, as they will be impacted by or could benefit from many of the MRV system's features.

The workshops would address the following topics (note that more than one of these topics could be covered in a single workshop):

- **Prioritization of sectors.** This involves reviewing the high-emitting sectors in Mexico and determining which should be the initial focus of an MRV system. Initial emphasis should be on sectors in which Mexico is actively involved in the design of NAMAs. The cement, iron & steel and housing sectors are natural candidates. However, there are likely to be benefits to considering related issues among a large number of sectors simultaneously, so sectors such as electricity, oil, and other high-emitting sectors should also be considered.
- **Prioritization of data.** This would focus on a review of the current data collected by the various agencies, including any data related directly to emissions or which could be used to calculate emissions or emissions intensity (e.g., production quantities, fuel consumption, process-related emissions, etc.). For the priority sectors, decisions would then be made on which data are most critical to estimations of GHG emissions and should be included in the MRV program.
- **Standardization of data systems.** The purpose of this process would be to review the manner in which relevant data are collected by the various agencies and then design a system under which this data would be reported, perhaps under a single system, such that all agencies would produce a consistent set of emissions estimates. For example, the goal would be to ensure that emissions estimated from fuel use in the cement industry are the same whether data from SENER, RETC's COA reports or Programa GEI emissions reports are considered.
- **Harmonization of methodologies for estimating GHG emissions.** Those bodies that produce or collect emissions reports would discuss the variety of methodologies for estimating GHG emissions and attempt to reach agreement on adoption of similar methodologies.
- **Assessment of capacity.** This step entails an evaluation of the capacity needed within each agency (and sector) to adopt the agreed standardized systems for data and emissions estimation methodologies. This includes a determination of any increased staffing levels, training, or other capacity-building needs; establishment of a realistic timeline for building this capacity and implementing the agreed systems; and estimating the international assistance required to facilitate this process.
- **Further development of verification procedures.** NAMAs will require estimation and verification of emissions *reductions*. This means that emissions baselines (or other reference levels) will need to be established for NAMAs, and trained auditors must be available to verify emissions reductions. It is feasible that, for those NAMAs supported by international finance, the costs associated with verification of emissions reductions will be part of the international support package. Therefore, this step will largely concentrate upon planning a process under which reference emissions levels can be established for NAMAs in Mexico and assessing the capacity of EMA to train a sufficient number of auditors of GHG emissions reductions.

Phase II of this MRV program would involve two steps: (1) obtaining the international assistance identified as a need in Phase I, followed by (2) implementation of the MRV system as designed in the earlier phase. CCAP estimates that Phase II will require one to two years to be fully completed.

VI. Conclusions

Mexico has made considerable progress in establishing domestic systems for the measurement, reporting, and verification of general environmental pollutants (including GHGs). In addition to reporting for compliance with domestic law and regulations, companies voluntarily pay for environmental audits using auditors certified by a domestic accreditation body. These audits help companies avoid future compliance issues. Moreover, many Mexican companies provide voluntary reports of company-level GHG emissions and emission abatement programs.

Although compliance regarding GHG reporting and the certification of GHG auditors have not been a major focus in the past, they are now getting more emphasis. However, GHG emissions reporting under Mexico's RETC program is not yet subject to third-party verification. As a basis for further regulation of GHGs in Mexico and for international MRV of NAMAs and crediting, companies could be required to have their GHG emission reports under the RETC program verified by auditors (or validation/verification bodies – VVBs) accredited by EMA.

In addition, important further work is needed to improve harmonization of GHG reporting methodologies and reporting formats in Mexico. Furthermore, the capacity of Mexican institutions to verify emission reports, to compare alternative data streams, and to analyze the results should be strengthened. This capacity building could play an important role in helping Mexico to achieve its GHG emission reduction objectives, to obtain international support for future NAMAs, and to gain access to sectoral and other new forms of finance from carbon markets.

However, harmonization of reporting requirements will be subject to some constraints. The MRV system required for a specific type of supported NAMA may differ depending on the funder. Different types of reporting requirements may be required to earn international sector credits, and those requirements may emerge from a new international framework or come in differing forms depending on the Annex 1 emission trading system that is buying the credits.

In addition, the precision needed in estimating emissions depends on how those estimates will be used. Less precision is needed in estimating a national inventory than when justifying the number of sector credits that have been earned. Less rigor is needed in verifying emission reductions for a voluntary project as opposed to a government-mandated program.

However, some industrial sectors are good candidates for harmonized reporting for a wide variety of purposes – those that have a homogeneous product, similar facility-level plants, and a limited number of firms that are all regulated at the federal level. In such sectors, a single rigorous measurement protocol could serve a variety of compliance and crediting regimes. For instance, in the cement industry, the facility-level reports required under the RETC program could also be used for corporate level reporting under Programa GEI, for calculating the sector's emissions in national inventories, and potentially for an internationally-supported sectoral program. Multiple types of measurement regimes impose excessive cost and complexity on an industry. Thus, Mexico should try to harmonize systems to the extent possible so that measurements of emissions and abatement in industrial sectors can simultaneously serve the purposes of domestic mandates, domestic market-based emission control programs, internationally supported NAMAs (for a variety of potential funders), and crediting programs associated with Annex 1 ETS.

Verification requirements may also differ substantially among domestic and international mitigation programs. In the case of government mandates, verification may be carried out by government agencies. In the case of unilateral NAMAs which will be recognized or registered by the UNFCCC, some international guidelines on verification (yet to be formulated) may need to be followed. In the case of supported NAMAs, third party verifiers may be needed and the requirements may differ across funders. In the case of sector crediting programs, the verification procedures may differ across Annex 1 trading systems unless common international standards are agreed upon.

The absence of clear, commonly accepted international guidelines for MRV of NAMAs and sectoral programs provides an opportunity for Mexico to play a leadership role. The country is already far ahead of many other developing countries in completing National Communications and in developing domestic MRV systems. Further development of those systems could provide an opportunity for the international community to learn lessons that the COP could use in devising guidelines for future NatComs, domestic MRV of unilateral NAMAs, and international MRV of supported NAMAs.

In addition, guidelines will need to be developed for future sector crediting programs. Mexico could provide a leadership role in this area as well. In addition to the above activities, this would require further work on establishing baseline emissions in various economic sectors. Emission abatement across those sectors could then be measured and verified relative to those baseline estimates. Work in this area could also help Mexico achieve its goals for domestic emission reductions and provide lessons that could be harvested for future international frameworks.

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Annex 1. Background Information for a NAMA in the Cement Sector

I. INTRODUCTION

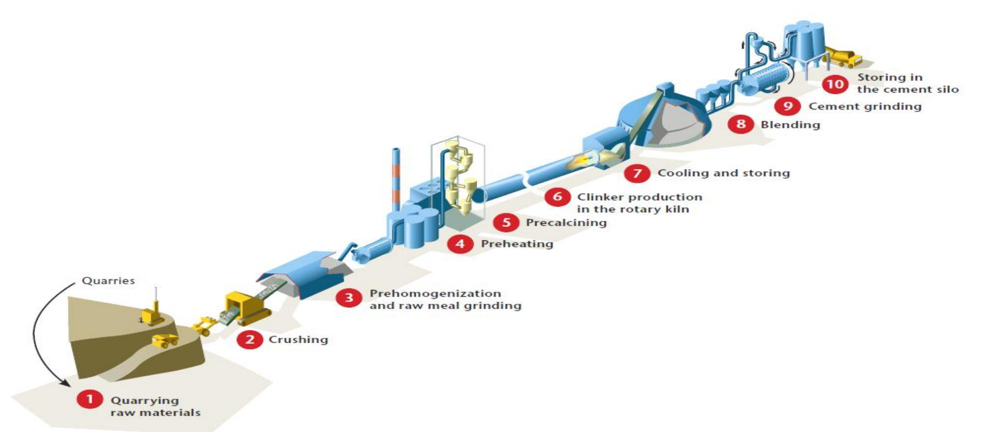
Objective of this Background Paper

The purpose of this paper is to compile and present background information on GHG mitigation options in the cement sector in Mexico, to lay the groundwork for Nationally Appropriate Mitigation Actions (NAMAs) in that sector, and to discuss options for measurement, reporting, and verification (MRV) of emissions abatement in the sector. This paper is one in a series prepared by the Center for Clean Air Policy for Abt Associates as part of the Mexico Competitiveness Program of USAID. Mexico's Ministry of Environment and Natural Resources (SEMARNAT) has requested USAID assistance to support Mexico's efforts to develop a low-carbon development strategy through 2020 and 2030, along with associated policy instruments. The context for this work is Mexico's announced national goal of reducing greenhouse gas (GHG) emissions to 30% below business-as-usual (BAU) levels by 2020, conditional on its receipt of sufficient international financial and technical support. In addition, Mexico's Special Program on Climate Change (PECC) includes a goal of reducing per capita emissions to 2.8 tons of CO_2e by 2050, equivalent to a reduction of total emissions to 50% of the 2000 level.

Overview of the Cement Industry

Broadly, the making of cement can be divided into two basic steps: clinker production and finish grinding. To make clinker, the cement industry sends limestone and other raw materials through crushing and grinding mills and into the cement kiln, where this mix is converted into cement clinker by heating to a temperature of about 1450° Centigrade. Then, the clinker is ground with gypsum and other minerals, and possibly blended with fly ash, slag, or other substitutes to produce cement in powdered form. These two basic steps can be further characterized by the overall process shown in Figure 1 below.

Figure 1. The Cement-Making Process



Source: World Business Council for Sustainable Development and the International Energy Agency, *Cement Technology Roadmap 2009*, http://www.wbcsd.org/DocRoot/mka1EKor6mqLVb9w903o/WBCSD-IEA_CementRoadmap.pdf.

The cement industry produces clinker by two major processes: the long-wet process and the dry process. The wet process is an older technology, less efficient than the newer dry-process technology, and is being phased out in the industry. The dry process is less energy-intensive than the wet process, and thus the dry process has steadily gained favor in cement production. In the U.S., wet-process plants accounted for 25 percent of production in 2002, while the dry process accounted for about 75 percent. Even with older facilities and longer kilns, the wet process shows somewhat smaller electric energy consumption because of the use of energy efficient wet grinding and the lack of the preheaters/pre-calciners found in dry plants. However, total energy use is greater in wet plants due to less efficient use of sensible energy in the kiln off-gases. As a result, it is assumed in the future that all new plants will be based on the dry process.

Background on Mexico's Cement Industry

Mexico's Historical Supply and Demand

Mexico's cement industry began with construction of the first cement plant in Mexico in 1906. After years of moderate growth, the industry expanded rapidly as a result of major government infrastructure investments after World War II. Since then, the industry has continued to grow at a good pace but experienced downturns after the Mexican financial crisis in the mid-1990s and the recent global economic recession.

Mexico's cement industry is among the most modern and efficient in the world today. All of the 50 kilns operating in the country's 31 cement plants are dry-process. Mexico's cement manufacturers are also using energy efficiency enhancing technologies such as preheaters and precalciners in most of their facilities. Moreover, a number of plants make use of some forms of low carbon alternative fuels.

Table 1 provides data on cement production in Mexico in recent years.

Table 1. Mexico's Cement Production

Year	Production (Mt)	Growth (%)
1998	27.7	
1999	29.4	6.1
2000	33.2	12.9
2001	32.1	-3.3
2002	33.4	4.0
2003	33.6	0.6
2004	35.0	4.2
2005	37.5	7.1
2006	40.4	7.7
2007	40.7	0.7
2008	47.6	17.0
2009	45.0	-5.5

Source: USGS, *Mineral Commodities Summary* (2010), *Minerals Yearbook* (2000, 2004, 2008), http://minerals.usgs.gov/minerals/pubs/commodity/cement/index.html#myb.

With the economic recession, production declined in 2009. Continuing economic weakness could restrain growth in the immediate period ahead. However, the dampening effect of the overall economic weakness could be offset to some extent by increased public sector spending.

As shown in Table 2, Mexico's largest cement firm is CEMEX, which owns 15 plants outright and has a minority share in 3 others. CEMEX accounts for nearly half of the country's cement production. The firm also owns 211 concrete plants, 67 land distribution centers, and 8 maritime centers in Mexico.[17] The second largest cement producer is Holcim-Apasco. This firm owns 6 cement plants and 23 wholesale distribution centers, 4 maritime terminals, and has a network of roughly two thousand retail distributors.[18] The cooperative, Cementos Cruz Azul, is next largest in size, with 3 cement plants that supply about 15% of the domestic market. Cementos Moctezuma owns two cement plants and Grupo Cementos Chihuahua (GCC Cemento) has three smaller plants. LaFarge Cementos is the smallest manufacturer, having entered the market through an acquisition only in 1999. It completed construction of a second plant in 2006.

Table 2. Mexico's Cement Firms

Company Name	Domestic Market Share in 2007	Number of Plants in 2007	Capacity in 2010 (Mt)
CEMEX Mexico	48%	15	33
Holcim-Apasco	22%	6	11
Cementos Cruz Azul	16%	3	8.5
Cementos Moctezuma	9%	2	6.5
GCC Cemento	4%	3	4
LaFarge Cementos	1%	2	0.5
Totals	100%	31	63.5

Source: International Business Strategies, 2008, *Cement Industry in Mexico*, http://www.internationalbusinessstrategies.com/market-research-reports/60600805.html.

About half of the demand for cement in Mexico is for the formal residential construction sector. The informal (do-it-yourself) sector consumes about one-third, and the remaining 20% is sold to large construction companies.[1] Grey cement accounts for the overwhelming majority of sales with a 94% share of the market, with mortar and white cement representing much smaller shares (5% and 1%, respectively). Mexico exports about 5% of its cement production, most of which goes to the United States.

[17] Orta, A. 2005, *Mexico's Cement Industry Market Overview*, obtained from www.buyusa.gov.
[18] Holcim-Apasco, 2008, Facts and Figures, retrieved November 10, 2008, from http://www.holcim.com/mx/EN/id/44238/mod/gnm0/page/editorial.html.

Institutions Relevant to Cement Industry Data

The cement industry's trade association is the Cámara Nacional del Cemento (CANACEM), which provides aggregated data on production and consumption of cement.

SENER, the Energy Ministry, is the agency within the Mexican government that regulates and monitors energy production in Mexico. It also collects and publishes data on fuel consumption and electricity use by various sectors, which it publishes on its Web site. The Ministry of Environment and National Resources (SEMARNAT) maintains the Pollutant Release and Transfer Database, which provides CO_2 emissions for some of Mexico's cement plants. All but one of Mexico's cement companies also voluntarily report their company-level CO_2 emissions to Programa GEI México, a public-private initiative formed through a partnership between the Ministry of Environment and Natural Resources (SEMARNAT), the World Business Council for Sustainable Development (WBCSD), the World Resources Institute (WRI) and the Mexican Coordinating Council (CCE) through its Business Council on Sustainable Development (CESPEDES).

II. BASELINE PROJECTIONS

In 2007, President Felipe Calderón's administration initiated a National Infrastructure Program (NIP). The NIP includes plans for upgrades to a wide range of existing structures as well as for construction of new facilities. Planned projects include 100 roadway construction projects, further development and new investments in 13 marine facilities, 3 new airports, and expansion of 31 that are already in place.[19] All of these projects are expected to require significant inputs from the cement industry. In anticipation of additional demand associated with the NIP, Mexico's cement manufacturers have announced plans to invest more than $1 billion in new plants and upgrades to existing plants.[20]

For a longer-term BAU projection of cement production and GHG emissions, we suggest using a methodology such as the following:

1. Forecast cement production as a function of future Mexican GDP
2. Forecast cement production, old vs. new capacity
3. Forecast energy requirements
4. Forecast energy requirements by fuel type
5. Forecast CO_2 emissions by fuel type
6. Calculate indirect CO_2 emissions
7. Calculate process CO_2 emissions
8. Total the CO_2 emissions

These steps are further described in the sections below.

1. Forecast Cement Production as a Function of Future Mexican GDP

One approach to estimating future cement production is to correlate it with Mexico's GDP. This may be oversimplified, but we have little information that seems to support a better methodology. Historical trends in total production make little sense. Different choices of historical start and stop years can cause the projections to fluctuate wildly, and arbitrary choices will drive the results.

In Table 3, historical production data from the USGS is shown relative to Mexico's GDP from 1998-2009. This data is plotted in Figure 2, where it is seen that in general, cement production is very sensitive to changes in GDP. Normalizing GDP and production to their 1998 values, we see that the slope of the relationship is very nearly 2.0, indicating that an X percent increase in GDP will result in a 2X percent change in cement production..

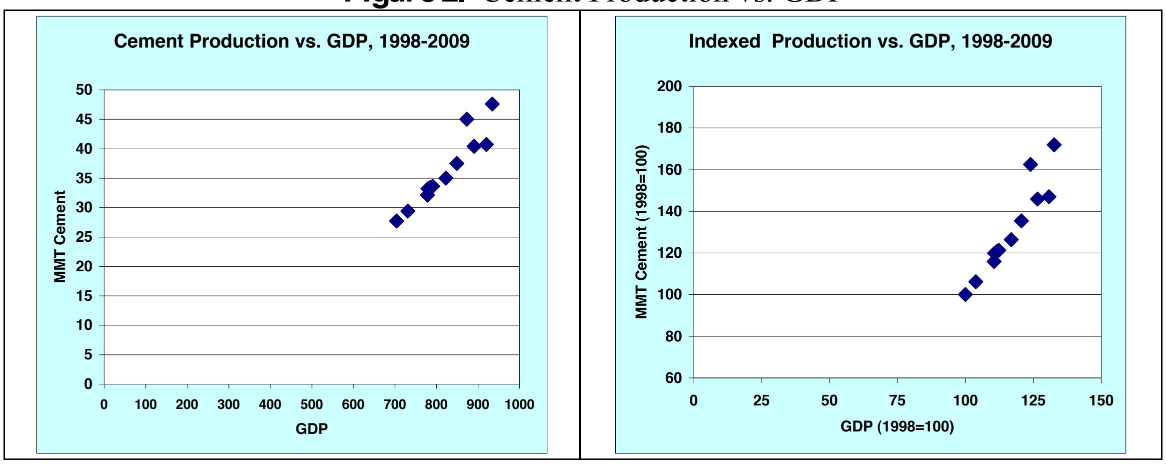
[19] U.S. Department of Commerce, 2008, *Procurement Opportunities: Mexico's National Infrastructure Program*, www.buyusa.gov.
[20] U.S. Department of Commerce, 2008, *Building and Construction in Mexico*, www.buyusa.gov.

Table 3. Cement Production vs. GDP

Year	Cement Production (Mt)	GDP (billion USD)
1998	27.7	704.0
1999	29.4	731.2
2000	33.2	779.5
2001	32.1	778.3
2002	33.4	784.7
2003	33.6	790.9
2004	35.0	822.8
2005	37.5	849.0
2006	40.4	890.8
2007	40.7	920.4
2008	47.6	934.3
2009	45.0	873.0

Sources: Cement production – see Table 1;
GDP – The Economist Intelligence Unit, http://store.eiu.com/.

Figure 2. Cement Production vs. GDP



On an indexed basis where 1998 cement production and GDP = 100, the forecast index would be:

Cement production index = 102.2 + (2.00/billion USD * GDP).

In terms of millions of metric tons (Mt) of cement production and billions of USD of GDP, the formula is:

Cement production = –28.30 Mt + (0.07863 Mt/billion USD * GDP).

Applying this formula to the GDP forecast through 2030, we obtain the projections given in Table 4. Note that this assumes that cement imports and exports remain a constant percentage of total production over time. If this is not a good assumption (e.g., if an export initiative was in the works, or if past exports were being shut off), these projections may have to be revisited and would require a regression of domestic consumption against GDP, with exports and imports added and subtracted, respectively, to get the domestic production projections.

Table 4. Historical and Projected Cement Production vs. GDP

Year	Cement Production (Mt)	GDP (billion USD)
2010	43.5	912.8
2011	46.0	944.4
2012	48.4	975.3
2013	51.0	1008.8
2014	54.1	1047.8
2015	57.4	1090.5
2016	60.9	1134.5
2017	64.4	1179.5
2018	68.0	1225.3
2019	71.7	1271.9
2020	75.4	1319.1
2021	79.2	1366.7
2022	82.9	1414.7
2023	86.7	1463.0
2024	90.6	1511.6
2025	94.4	1560.5
2026	98.3	1609.7
2027	102.2	1659.2
2028	106.1	1709.2
2029	110.1	1759.7
2030	114.1	1810.9

Source: GDP – The Economist Intelligence Unit, http://store.eiu.com/.

However, the planning department of Mexico's cement chamber (CANACEM) does not project as strong a growth (5% per year) for the industry as the GDP figures in Table 4 would indicate. They foresee an annual growth rate in cement production of about 3%, more similar to recent historical trends. In the end, we agreed to use the CANACEM projections for cement production but include the above calculation based upon GDP to illustrate the uncertainties in determining BAU baselines. The final cement production baseline that we adopted is shown in Table 5.

Table 5. Adopted Baseline for Cement Production in Mexico

Year	Cement Production (Mt)
2000	33.2
2005	37.5
2010	43.5
2015	51.0
2020	59.1
2025	68.6
2030	79.5

Sources: CCAP and CANACEM.

2. Forecast Cement Production, Old vs. New Capacity

Efficiencies vary between older facilities and new state-of-the art facilities. Also, CO_2 mitigation opportunities typically vary between the two. For these reasons, it is useful to identify old vs. new production and to forecast when new facilities may be needed. At present, there is overcapacity in the Mexican cement industry.

Mexico's current cement capacity is about 63.5 million tons (see Table 2). From the production projections made above, this would suggest that new capacity would not be needed until sometime between 2015 and 2020. To further refine this estimate, two questions need to be to considered:

- Is any of this existing capacity expected to retire? If so, when? For our analysis, we have assumed that no capacity will be retired before 2030.
- At what point will new capacity be built? The methodology adopted here assumes that this occurs when existing capacity is 90% utilized. If a smaller amount, say 70%, is more appropriate, then new capacity would need to come in sooner and in greater amounts.

3. Forecast Energy Requirements

Since blending is a key mitigation option for the Mexican cement industry, we need the baseline to be explicit in terms of the amount of blending assumed. In a presentation to CANACEM, CCAP noted that CEMEX averaged a 78 percent clinker factor in 2006.[21] Absent more recent and/or more complete data, we use the CEMEX value industry-wide, and note that it is a proxy value to be improved upon later. For our BAU forecasts, we hold the clinker factor constant over time.

Multiplying cement production by the clinker factor provides a forecast of clinker production. We then examine thermal efficiency of the kilns, seeking to estimate the Btu (or gigajoules) of energy per ton of clinker and/or cement. This will differ for the existing capacity and for the new capacity that will likely be built in future years.

For existing cement plants, we can extract information from CEMEX CDM documents[5] and other sources. This gives an average energy efficiency for the Mexican industry of 3.7 GJ/t clinker. For new capacity, we assume that it will all be at world efficiency standards. After consulting EU benchmarking studies, the CSI's GNR database, and CANACEM, we chose a value of 3.2 GJ/t clinker for all new cement capacity in Mexico.

To calculate total energy needs, we divide the tons of clinker (or cement) by the appropriate efficiency factors. This is done separately for existing and new capacity, and these are then added together to get total energy consumption.

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[21] CDM Project Design Document, 2007. "Project 1356: Reducing the Average Clinker Content in Cement at CEMEX Mexico Operations" and associated materials, available at http://cdm.unfccc.int/Projects/DB/SGS-UKL1190380419.97/view.

4. Forecast Energy Requirements by Fuel Type

The energy use by fuel type for the cement industry from was taken from SENER data for 1998-2008.[22] In 2008, this produced the fuel mix shown in the second column of Table 6 for Mexico's cement sector. We rounded these values and used the resulting fuel mix to forecast annual energy consumption by fuel type for 2009-2030.

Table 6. Cement Sector Fuel Mix for 2008 and Future Projections

Fuel Type	2008 Share of Fuel Mix (%)	Post-2009 Share of Fuel Mix (%)
Traditional Fuels	96.1	96.0
Petcoke	64.8	65.0
Fuel Oil	20.2	20.0
Coal	5.4	5.0
Diesel	0.2	0.0
Natural Gas	5.5	6.0
Alternative Fuels	3.9	4.0
Liquid wastes	2.2	2.0
Solid wastes	1.0	1.0
Tires	0.7	1.0
Total	100.0	100.0

Sources: SENER, 2009, *Balance Nacional de Energía 2008*, http://www.sener.gob.mx/res/PE_y_DT/pub/Balance_2008.pdf.

5. Forecast CO_2 Emissions by Fuel Type

We next converted the fuel use into energy-related CO_2 emissions. CO_2 emission factors (EFs) vary by fuel type, and the EFs of some fuels, such as coal and municipal solid waste (MSW), show significant variations among different sources. Table 7 gives the CO_2 emission factors from that we adopted for our analysis.

Table 7. Fuel CO_2 Emissions Factors

Fuel Type	EF (tCO_2/GJ)
Petcoke	0.09679
Fuel Oil	0.07469
Coal	0.08900
Diesel	0.06940
Natural Gas	0.05029
Liquid wastes	0.074
Solid wastes	0.083
Tires	0.0815
MSW	0.0395

Sources: Liquid and solid wastes: CSI, Default CO_2 Emission Factors for Fuels, http://www.wbcsdcement.org/pdf/report/co2_protocol.xls; all others, US EIA, converted to tCO_2/GJ from http://www.eia.doe.gov/oiaf/1605/ggrpt/excel/CO2_coeffs_08.xls.

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[22] SENER, 2009, *Balance Nacional de Energía 2008*.

6. Calculate Indirect CO_2 Emissions

The indirect CO_2 emissions from electricity will be a small part of the overall emissions, and even a smaller part of what might change as a result of proposed mitigation efforts. Accordingly, the precision of this factor has little effect on the overall findings.

The Cement Sustainability Initiative (CSI)[23] gives default CO_2 emission factors for grid electricity. For our analysis, we used an approximation of their most recent values for Mexico, 0.580 tCO_2/MWh, to calculate indirect CO_2 emissions.

7. Calculate Process CO_2 Emissions

Process emissions from the kiln are more than half the total emissions from cement-making. The emissions per ton of clinker are relatively fixed from plant to plant, with only small variations for treatment of cement kiln dust, limestone quality, etc. The major differences in process emissions will instead be the result of cement blending and clinker substitution which reduces the amount of kiln-produced product per ton of cement.

The CSI and IPCC have developed an elaborate procedure for computing cement kiln process emissions. However, these detailed variations are better suited for individual plants, rather than for an entire industry.

Absent detailed plant-by-plant data, a reasonable estimate of process emissions can be made using basic default factors and keeping these constant over the forecast period. We again adopted the value suggested by the CSI,[7] which states that: "In the absence of better data, a default of 525 kg CO_2/t clinker shall be used. This value is comparable to the IPCC default (510 kg CO_2/t) corrected for typical MgO contents in clinker."

8. Total CO_2 Emissions

This is simply the sum of direct, indirect, and process emissions.

[23] WBCSD, 2005, *CO_2 Accounting and Reporting Standard for the Cement Industry,* Appendix 2, June, available at http://www.wbcsd.org/web/publications/cement-tf1.pdf.

III. MITIGATION OPTIONS

The production of cement is a very energy-intensive and greenhouse gas-intensive process. In each of the stages of production – from the quarrying of raw materials to the storage and shipment of the finished products – CO_2 is emitted directly from the fuel consumption and/or indirectly from the electricity use.[24] Each stage, in theory, offers opportunities for greater efficiency and/or lower CO_2 emission intensity.

However, while the set of all mitigation opportunities may be numerous, the subset that offers the major opportunities is considerably smaller. And in Mexico's case, where the industry is already relatively energy-efficient and modern, the major opportunities are smaller still.

CO_2 emissions from cement production come from three main sources: direct emissions from fuel combustion, indirect emissions from electricity use, and process emissions from the production of clinker. Mathematically, we can use the following formula to estimate cement-related CO_2 emissions

$$
\begin{aligned}
CO_2 \text{ emissions} = \; & (\text{tons of cement produced}) \times (\text{fuel Btu/ton}) \times (\text{carbon/Btu}) \\
+ \; & (\text{tons of cement produced}) \times (\text{MWh/ton}) \times (\text{carbon/MWh}) \\
+ \; & \text{clinker process emissions} \\
- \; & CO_2 \text{ sequestered}
\end{aligned}
$$

Using this formula, we can identify four primary pathways, or levers, to reduce CO_2 emissions from cement production.

1. ***Improving thermal and electric efficiency.*** The energy used in kiln processes and in electricity-driven applications is largely fossil fuel based. Reducing the amount of energy used reduces the associated CO_2 emissions.
2. ***Increasing use of alternative fuels.*** Kilns are typically fueled by fossil energy, such as coal, pet coke, and fuel oil. Some of these energy needs can be provided by less carbon-intensive alternative fuels such as municipal solid wastes, biomass, tires or sewage sludge. By lowering the carbon intensity of the energy supply, these alternative fuels reduce CO_2 emissions.
3. ***Clinker and cement substitution (blending).*** The clinker produced in kilns is the main component in most types of cement, comprising up to 95 percent of the content of Portland cement. Flyash, slag, and other lower-carbon materials that have cementitious properties can substitute for some of this clinker. By blending or substituting these alternative materials into the cement, the

[24] Additionally, substantial CO_2 emissions are inherent to the clinker production process. Mitigation opportunities for these process emissions do not generally involve efficiency measures but consist of cement blending and other clinker substitution measures that reduce the amount of clinker needed to meet cement demand.

"clinker factor" is lowered, and CO_2 emissions are lowered as a result of the avoided kiln production.[25]

4. ***Carbon capture and storage (CCS).*** If CO_2 can be captured and stored securely with near-permanence, CO_2 emissions to the atmosphere are avoided. While CCS technologies have not yet attained commercial and economic viability, they may in the future. If so, the relatively CO_2-rich emissions from cement kilns may offer an attractive application for CCS.

These four pathways provide a framework for identifying and evaluating CO_2 emission reductions in the cement industry, and are described in more detail below. In this examination, it is noted that Mexico's cement industry is already among the most energy-efficient and modern in the world. Due to this high degree of efficiency, CO_2 reduction options that might be applicable elsewhere in the world are, to a large extent, already reflected in Mexico's baseline projections. The primary mitigation options for Mexico's industry lie largely in the areas of increased blending and greater use of alternative fuels, rather than in more expensive process and efficiency improvements.

While the discussion below describes each of the aforementioned mitigation pathways separately, we also note that it is often the case that actions taken in one area can have an influence on the CO_2 mitigation potential of other actions. For example, if energy efficiency measures reduce the carbon intensity of clinker production, then greater use of clinker substitutes will have a somewhat lesser effect on CO_2 emissions relative to a less efficient kiln line. Accordingly, the net reductions possible from all actions taken together will likely differ from the simple summation of the effects of each action individually.

Improving Thermal and Electric Efficiency

By using state-of-the-art technologies in new cement plants and retrofits of energy-efficiency equipment where economically viable, cement producers can reduce energy consumption and the associated emissions. But this general tendency may be less applicable to Mexico, where facilities are already among the most efficient globally.

The cement kilns are by far the most energy-intensive parts of the overall cement operations. There are large differences in efficiency between the older wet-process plants and the newer dry-process plants. As seen in Table 8, and using U.S. historical data, dry-process plants save more than 30 percent of the energy requirement per ton of product, relative to the older wet process plants. For this reason, the new capacity built today is nearly all dry process, and the remaining wet process plants are gradually being phased out worldwide. However, in Mexico it is already the case that the plants are all dry process, with their comparably greater efficiencies.

[25] In some places, notably in the United States, the alternative materials are generally not blended into the cement at the plant, but are instead used as a cement substitute in the concrete manufacturing stage. While this practice may not lower the clinker ratio as measured by the cement producer, the overall effect in mitigating CO_2 emissions is comparable.

Table 8. Energy Consumption by Kiln Process

Energy Consumption by Process

(Thousands of BTUs per Equivalent Metric Ton)*

	1972	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	% Change 08/72	08/07
Fuel and Electricity													
All Plants	7,438	5,040	4,982	4,930	4,858	4,763	4,755	4,699	4,649	4,703	4,641	-37.6	-1.3
Wet-Process Plants	7,998	6,223	6,250	6,442	6,676	6,647	6,807	6,387	6,464	6,485	6,448	-19.4	-0.6
Dry-Process Plants	6,895	4,713	4,673	4,655	4,498	4,434	4,407	4,433	4,375	4,434	4,384	-36.4	-1.1
Fuel													
All Plants	6,931	4,519	4,457	4,406	4,337	4,240	4,245	4,180	4,131	4,181	4,115	-40.6	-1.6
Wet-Process Plants	7,498	5,743	5,744	5,959	6,172	6,135	6,291	5,879	5,949	5,979	5,935	-20.8	-0.7
Dry-Process Plants	6,393	4,181	4,144	4,124	3,974	3,909	3,899	3,913	3,856	3,909	3,856	-39.7	-1.4
Electricity *(kWh per Equivalent Metric Ton)*													
All Plants	143	153	154	154	154	153	149	152	152	153	155	8.4	1.3
Wet-Process Plants	142	142	149	141	148	150	151	149	151	148	150	5.6	1.4
Dry-Process Plants	142	156	156	156	154	154	149	153	152	154	156	9.9	1.3

**Equivalent Metric Ton = weighted average of 92% clinker production plus 8% finished cement production*

Source: PCA U.S. and Canadian Labor-Energy Input Survey

Source: Portland Cement Association, *2009 North American Cement Industry Annual Yearbook*, Table 46, http://www.cement.org/bookstore/profile.asp?store=&pagenum=1&pos=0&catID=&id=16958.

For some producers, even those using dry kiln technologies, one of the most significant ways to improve energy efficiency in the cement sector is upgrading to more efficient kilns. Current state of the art is the dry manufacturing process with preheater and precalciner technology. Based on the "Getting the Numbers Right" (GNR) data collected by the Cement Sustainability Initiative (CSI), the weighted average of the specific thermal energy consumption for the dry kiln type in 1990 was 3,605 MJ/t clinker, and in 2006 was 3,382 MJ/t clinker, a reduction of around 220 MJ/t clinker (6%) over 16 years.[26]

The thermal efficiency of an installation is largely defined by its original engineering design. However, after installation, the efficiency at which the machinery is operated and maintained is key to ensuring that maximum potential operational efficiencies are achieved. This operational efficiency varies by technology, and is hard to measure, but is an important aspect of energy and emissions management.[10]

In Mexico, the opportunities for kiln improvements appear to be limited. With the existing plants already operating at a relatively high efficiency compared to other countries, remaining efficiency improvements tend to be relatively higher cost and provide lower energy and GHG benefits. CCAP research indicates that most potential improvements in thermal energy efficiency in Mexico's cement sector are either very expensive and/or precluded by other factors (plant location, engineering limitations, etc.).

Energy efficiency can also be improved by reducing the consumption of electricity, and this in turn reduces the indirect emissions associated with its generation. There are various technologies and measures for reducing electricity intensity during the production of cement, such as the following:

- *High Efficiency Grinding Technologies.* In general, the energy efficiency of ball mills used in finish grinding is relatively low. Installation of roller presses and

[26] World Business Council for Sustainable Development and International Energy Agency (WBCSD/IEA), 2009, *Cement Technology Roadmap 2009*, https://www.iea.org/papers/2009/Cement_Roadmap.pdf, p. 6.

roller mills, in combination with ball mills, can significantly reduce power consumption at the finish mill.

- *High Efficiency Motors.* In a typical plant, there are hundreds of electric motors of different sizes that are used to drive fans, rotate the kilns, transport materials, and propel the grinding of raw material. Installing higher efficiency motors will increase the energy efficiency of a cement plant by decreasing the energy required to power individual motors.
- *Adjustable Speed Drives.* During the cement production process, drives consume a great amount of energy. To improve the energy efficiency of the drive system, a plant must increase the efficiency of the motors or reduce energy losses through decreased throttling or installation of adjustable speed drives. Since most motors are fixed speed, but often operate at partial or variable load, adjustable speed drives can optimize energy use.
- *High Efficiency Classifiers.* Classifiers (also known as separators) sort and separate fine particles from the larger particles; large particles are sent again to the mill. Standard classifiers may not have a sophisticated sorting mechanism, sending large and some fine particles back to the mill, lengthening the grinding process and using extra power in the grinding mill. High efficiency classifiers reduce over-grinding by more cleanly separating the materials. In addition to providing an energy benefit, high efficiency classifiers improve product quality.

While Mexico's cement facilities are not particularly efficient in their use of electricity, and the list above suggests numerous opportunities for more efficient use of electricity at cement plants, the collective savings in energy and GHG emissions are likely to be modest. Per U.S. data, the use of electricity accounts for only about 10-12 percent of the total energy consumption of cement production, with the rest being direct fuel consumption, primarily coal and petroleum coke.[27] Further, because the underlying fuel mix from electricity generation tends to be less carbon-intensive than the fuels used in the kilns, these indirect emissions from electricity are usually less than one-tenth of the total plant emissions. As such, even a ten percent efficiency improvement in electricity use will affect overall cement plant emissions by only about one percent. In general, unless new equipment is needed for other reasons, upgrading electric components for GHG reductions tends to be a high-cost mitigation option with modest GHG savings.

In addition to reducing CO_2 emissions by more efficiently using electricity at cement plants, the CO_2 footprint can be lowered by reducing the CO_2 intensity of the electric power grid. In the electric power sector, emissions intensity can be reduced by a variety of actions that either improve the energy efficiency of generating units or increase the proportion of low-carbon or non-carbon sources in the generation mix. These actions can be undertaken by the electric utility, or by independent power producers that are supplying to the grid. However, from the perspective of a cement plant, while the amount of electricity consumed is controllable, the CO_2 intensity of that power is not. Accordingly, for this analysis, we consider electricity grid CO_2 reductions as being outside of the scope of cement sector mitigation.

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[27] Portland Cement Association, 2009, *2009 North American Cement Industry Annual Yearbook*, Table 43, http://www.cement.org/bookstore/profile.asp?store=&pagenum=1&pos=0&catID=&id=16958.

Increasing Use of Alternative Fuels

Cement kilns can be fueled with a variety of energy sources. If a portion of the fossil fuel supply is replaced by alternative low-carbon fuels in the cement kiln, the lower carbon intensity of the fuel mix will result in lower CO_2 emissions.

Alternative fuels could include scrap tires, wood waste, agricultural residues, dried sewage sludge, MSW, plastics, used oil, petroleum refinery waste, and landfill gas. Generally, mixed fuel can be 20-25% less carbon intensive than coal, with the reduction of CO_2 emissions dependent upon both the heat content and carbon content of the alternative fuels selected.[28] Additional benefits can be achieved through use of alternative fuels by preventing unnecessary land-filling of wastes and eliminating the associated methane emissions from the landfill.

Cement kilns are particularly well-suited for using alternative fuels for two reasons. First, the energy component of alternative fuels is used as a substitute for fossil fuels. Second, the inorganic components (e.g., ashes) can be integrated into the clinker product.

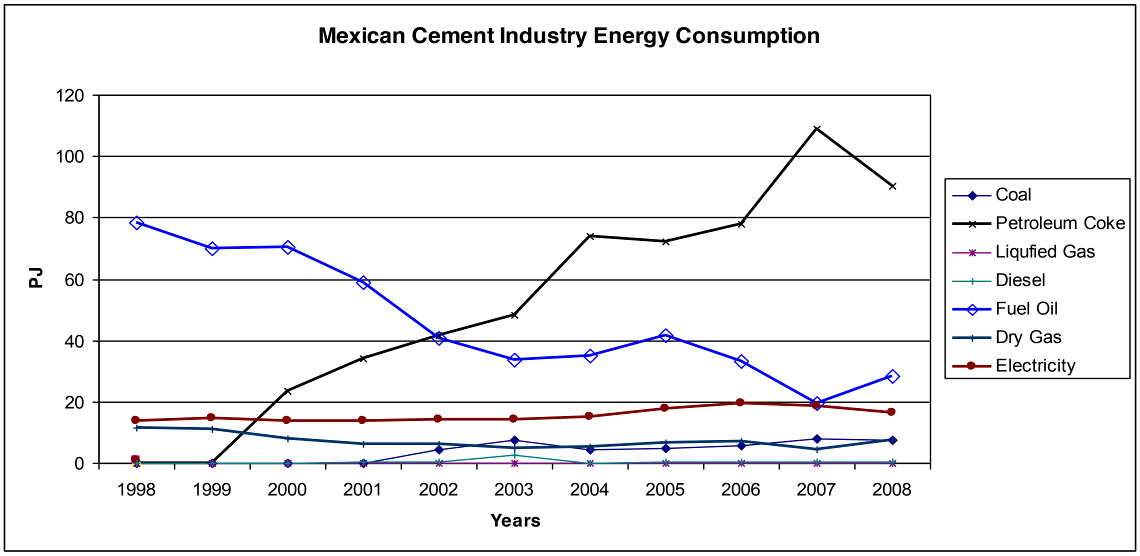
Mexico's Cement Fuel Mix

Fuel combustion emissions account for around 30 to 40 percent of the cement industry's total emissions, depending on the specific kiln energy consumption. Fuel also contributes about the same share of the overall costs. As mentioned preveiously, the Mexican cement industry is one of the most efficient in the world, composed almost entirely of rotary kilns with preheater and precalciner, a technology mix that requires about 3.5 GJ/t clinker in Mexico. Given the industry's current fuel mix (see Table 6), this would produce approximately 310 kg CO_2 / t clinker or 12.4 $MtCO_2$.in 2008.

The Mexican cement industry's fuel mix has changed significantly over the last ten years (see Figure 3). The most significant shift has been the replacement of fuel oil with pet coke, the most carbon intensive fuel in the mix, increasing the industry's overall CO_2 emissions. This change has apparently been driven primarily by PEMEX's efforts to more completely refine its petroleum, leaving petcoke (rather than fuel oil) as the final waste product. Since pet coke requires higher temperatures to burn, compared to most fuel oils, this switch in fuels can also worsen energy efficiency. It is important to note that, before 2000, pet coke was not used in cement kilns. This trend appears to have temporarily reversed itself in 2008, with fuel oil replacing some pet coke. Also in that year, the sector's overall energy consumption fell by the largest margin in ten years, just under 6%, as a result of the economic downturn.

[28] WBCSD/IEA, 2009, *Cement Technology Roadmap 2009: Carbon Emissions Recutions up to 2050*, https://www.iea.org/papers/2009/Cement_Roadmap.pdf, p. 9.

Figure 3. Mexico Cement Sector Energy Consumption by Fuel Type



Source: SENER, 2009, *Balance Nacional de Energia 2008*.

As with other energy intensive sectors, one potential mitigation option for the cement industry is to replace high-carbon fuels with fuels with less carbon content or those that are carbon neutral. The high temperatures reached in the kiln allow for a wide range of materials to be considered as alternatives for conventional fuels. Alternative fuels can range from plastics, solvents, tires and waste oils to MSW, sludge and biomass, even hazardous wastes. Some additional benefits of using waste as alternative fuels are energy recovery and waste management.

Mexico's cement producers currently use only a modest share of alternative fuels in their fuel mix. In 2006, alternative fuels are estimated to have comprised less than two percent of the industry's fuel mix.

In contrast, cement industries in other countries have moved faster in their use of alternative fuels. In the U.S., for example, the use of alternative fuels has been rising as a share of the fuel mix. In 2008, alternative fuels averaged about 495,000 Btu per equivalent metric ton, equal to more than 14 percent of the direct fuel mix.[29] This suggests that there is significant potential for greater use in Mexico's industry.

The extent to which alternative fuels can replace conventional fuels varies with their quality and availability. Many of these fuels (e.g. sludge, MSW, biomass) need to be treated to reduce water content and boost their calorific value. Technologies also need to be in place to ensure that the dosing and feeding of the fuel maximizes the kiln's energy use. In addition, adequate storage capacities for alternative fuels are required. All things considered, the most likely determining factor for the use of these fuels will be the cost.

[29] Portland Cement Association, 2009, *2009 North American Cement Industry Annual Yearbook*, Table 43, http://www.cement.org/bookstore/profile.asp?store=&pagenum=1&pos=0&catID=&id=16958.

On average, alternative fuels can provide about 17% of the fuel use. However, there are examples of cement plants around the world that have reached replacement shares of up to 78%.[30] Realizing this potential, the Mexican National Chamber of Cement (CANACEM) saw an opportunity to reduce its fuel costs and approached the Mexican Environment Ministry (SEMARNAT) to come to an agreement on the use of alternative fuels. SEMARNAT considered the offer and, after an assessment of other potential hazardous emissions from alternative fuels (e.g. chlorine, heavy metals, furans, sulphur, PCBs), signed an agreement (Convenio de Coporocesamiento) with CANACEM, whereby it would give each cement plant authorization to use alternative fuels (not including MSW) for a particular share of its fuel use in 1996. The latest authorized shares amount to 30% of total fuel use for 30 plants (out of the existing 32).

In spite of the agreement, according to Professor Porfirio Caballero of the Instituto Tecnologico y de Estudios Superiores de Monterrey, an expert on alternative fuel use in the cement sector in Mexico, the share of alternative fuels in the cement industry is 1-2%. This appears to be consistent with previous studies on the sector. Mexico, however, appears to have a growing amount of alternative fuel providers, mostly concentrated on waste treatment. Members of this niche industry not only treat the waste but transport it to the plant and can even feed it into the kiln.

Due to their high availability and proven use in Mexican cement kilns, this study will focus on waste tires and MSW. Other alternative fuels, such as hazardous wastes, produce emissions that are highly regulated. The availability of biomass, on the other hand, is greatly determined by geographical location. Over 30% of Mexico's cement capacity is located in areas with dry climate, which would force cement plants that want to burn biomass to pay high fees for transportation, as well as biomass processing (e.g. pelletization).

To avoid technical problems in the kiln, such as overheating, alternative fuels have a specified maximum substitution rate. For example, MSW has a substitution limit of 30% while tires have a limit of 20%. Therefore, in the case of tires, even if SEMARNAT authorizes cement plants to burn a share of up to 30% of alternative fuels, this share cannot be met solely with tires. The best fuel switch mitigation option is to replace the most carbon-intensive fuel, pet coke, with the least carbon-intensive fuel, MSW. If 30% of the energy produced from pet coke was replaced with MSW in the cement industry's 2008 fuel mix, the sector would reduce its emissions by 2.3 Mt CO_2. If both MSW and tires are used at their maximum capacity, 30% and 20% respectively, to replace pet coke, the emission reductions would be the largest at 2.7 Mt CO_2. This information is summarized in Table 9.

[30] Haile-Meskel, Y., 2008, "Environmental and Economic Benefits of Biomass Fuel Use in Cement Production," in *Bio-carbon Opportunities in Eastern and Southern Africa: Harnessing Carbon Finance to Promote Sustainable Forestry, Agro-forestry and Bio-energy*, p. 217-232.

Table 9. Emissions Reductions from the Use of Tires and MSW

Alternative Fuel / Fuel Replaced	MSW Fuel Share	Tires Fuel Share	Emission Reduction ($MtCO_2$)
MSW/Petcoke	30%	0%	2.3
Tires/Petcoke	0%	20%	0.41
MSWTires/Petcoke	30%	20%	2.7

Source: CCAP calculations.

As mentioned above, costs will become the determining factor when choosing a specific fuel mix. The primary aim of a cement sectoral NAMA should be to reduce the relative prices between less carbon-intensive alternative fuels and more carbon-intensive traditional fuels. One way to achieve this goal is to finance projects that would reduce the costs associated with the processing and the transportation of the alternative fuel. Cement plants in the north of Mexico are willing to burn waste as long as it meets certain standards and is delivered directly to the plant. Proof of this is the surge of waste processing companies in that region. However, other parts of the country are not as progressive. For example, the state of Hidalgo, in the center of Mexico, hosts five of the 32 plants in country, but the only two landfills in the state do not process MSW. Building roads to and from the landfills to the cement plants, as well as constructing a processing facility for MSW, would not only help supply cement plants with alternative fuels but would help the state manage its waste. If long term contracts (10-15 years) can be established for the ownership of the MSW between the municipal authorities and a private company, clear price signals can be sent to cement producers.

However, the largest barrier to keeping relative prices low for alternative fuels continues to be subsidized prices for carbon intensive fuels produced by PEMEX, such as pet coke and fuel oil.

Alternative Fuels Considerations

Using alternative fuels, particularly those with uncertain supplies, can raise issues of supply availability, dependability, and consistency. Location issues can constrain the use of fuels like MSW, as cement plants are often not near landfills. In addition, MSW is typically a low-Btu density fuel, meaning that more tons are needed (compared to fossil fuels) to supply a given amount of energy. When transportation costs and emissions are factored in, the MSW option may not be cost-effective.

Where alternative fuels are locally available, other barriers can limit their usefulness. For instance, MSW requires processing and treatment before it can be used as an alternative fuel by the cement industry, both because of health hazards and because of resulting effects on the quality of the cement. Alternative fuels may require unique material handling systems (e.g., to reduce sludge moisture) before they can be useful for cement production.

Another potential barrier to the use of alternative fuels is more legal in nature, as difficulties in obtaining long-term supply contracts can deter companies from making changes in their fuel handling equipment and operating practices. Cement plants need to be able to establish long-term contracts with municipalities to secure a steady supply of MSW or processed fuel and to ensure a consistent quality of these products. MSW is owned and managed by municipalities, and local administrations are generally subject to term limits of three years. To date, term limits for local government administrations has proved to be an impediment to the creation of these long-term contractual arrangements.

Clinker and Cement Substitution

Blending agents can replace some portion of the clinker in cement, thereby reducing the quantity of clinker needed to produce a ton of cement. The production and use of blended cements depends largely on the additives that are available, as well as the environmental and other regulations in force.

There are three materials that are primarily used for cement blending: high volume fly ash from coal-fired power plants, blast furnace slag from iron and steel plants, and naturally occurring volcanic ash (pozzolans). Some blending materials can also substitute for limestone during clinker production and reduce the associated energy demand by lowering the melting point in the formation of the clinker phases. The use of coal fly ash, blast furnace slag, and natural pozzolans reduces the CO_2 emissions intensity of a ton of cement from fuel use as well as from the calcination of limestone.

Current Blending Practices

Use of blending materials – either in making a blended cement or in substituting for cement in the concrete manufacturing – varies widely from country to country, and often reflects the extent of local steelmaking and power generation. In the United States, use of flyash and slag as cement replacements has grown considerably in recent years. In 2008, total U.S. consumption of Portland cement was 93.5 million metric tons.[31] Fly ash use in concrete and concrete products was about 11.4 million metric tons,[32] and slag usage was 2.7 million metric tons.[33] Collectively, fly ash and slag comprised about 13 percent of the cementitious materials used in U.S. concrete manufacturing in 2008.

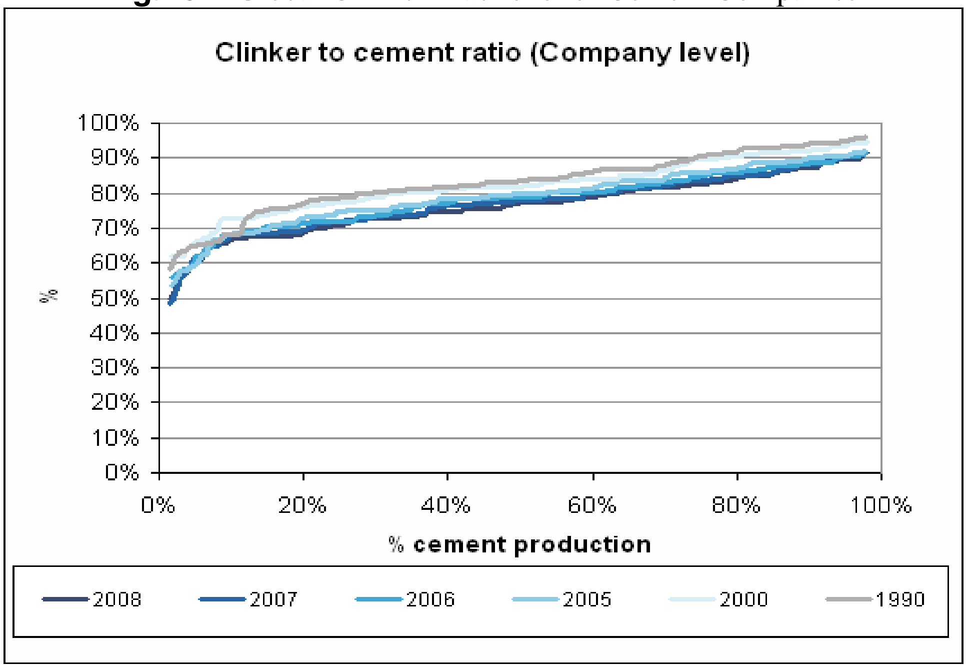
[31] Portland Cement Association, 2009, *North American Cement Industry Annual Yearbook 2009*, Table 9, http://www.cement.org/bookstore/profile.asp?store=&pagenum=1&pos=0&catID=&id=16958.
Including 3.0 Mt of masonry cement, total U.S. cement consumption was 96.5 Mt. Of this amount, 11.5 Mt were imports. Because the U.S. practice is generally to introduce fly ash and slag at the concrete manufacturing stage, cement consumption is a more appropriate measure for determining blending percentages than domestic production.

[32] In 2008, fly ash use for "concrete/concrete products/grout" was 12,592,245 short tons. See American Coal Ash Association, 2009, *2008 Coal Combustion Product Production and Use Survey Report,* http://acaa.affiniscape.com/associations/8003/files/2008_ACAA_CCP_Survey_Report_FINAL_100509.pdf.

[33] Slag Cement Association website, *U.S. Slag Cement Shipments*, accessed June 30, 2010, http://www.slagcement.org/shared/custompage/custompage.jsp?_event=view&_id=445505_U128801__148636.

Globally, there is a broad range of industry practices in cement blending, reflecting the local availability and cost of blending materials, and also variations in local usage practices and requirements. When we examine the variation in the clinker-to-cement ratio – also known as the "clinker factor" – we see in Figure 4 that most of the companies have an average clinker factor ranging between 70 and 85 percent. Further, we can see that average clinker factors have declined 5-10% over the reporting period, resulting in substantially reduced emissions.

Figure 4. Global Clinker Fractions for Cement Companies



Source: WBCSD, 2006, GNR Reporting Project, *Table 339: Clinker to cement ratio*, http://www.wbcsdcement.org/gnr-2008/world/GNR-Indicator_339-world-allyear.html.

Blending with pozzolans used to be quite high in Mexico. Production of blended pozzolanic cements had increased to nearly 45% of output in 1995,[34] and natural pozzolans were reported to be readily available in several parts of the country. The Mexican standard for blended cement allows 10-30% of pozzolans to be added per ton of cement. Currently, blended cements use an average of 20% pozzolans, while in 1990 and 1994, the share of blended pozzolan cements was 45%.

Conflicting reports concerning the availability of blending resources in Mexico have surfaced. According to the IEA, waste slag availability is limited, and natural pozzolans can only obtained from certain locations. Fly ash resources are of poor quality, and therefore of little value to cement producers[35]. The historic data belies this, especially with respect to the availability of natural pozzolans. The use of waste ash from petcoke

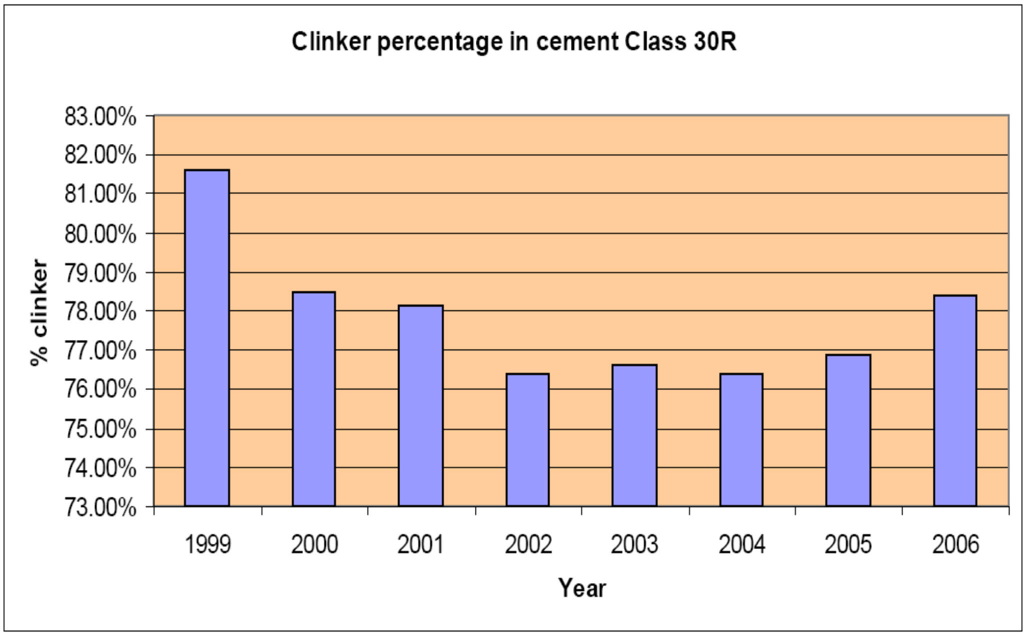
[34] Sheinbaum, C. and Ozawa, L., 1998, "Energy Use and CO_2 Emissions for Mexico's Cement Industry," *Energy*, **23** 9.

[35] Malhotra, V. M., and Hemmings, R. T., 1995, "Blended Cements in North America - A Review," *Cement and Concrete Composites*, 17.

electricity generating plants is also being explored via a pending CDM project, but this waste ash needs to be combined with commercially mined fluorite in order to react properly with the limestone and gypsum to create usable cement.

The clinker factor for CEMEX, the largest cement company in Mexico, has varied significantly over the last few years, as illustrated in Figure 5. In 1999, CEMEX blending in Class 30R cement, the most popular form of cement, was only 18.75%. This increased to about 23.5% in 2002 and then decreased slowly from that year through 2006.

Figure 5. Clinker Content of Class 30R Cement Produced by CEMEX in Mexico



Source: See footnote 24.

More recently, Mexico's use of clinker and cement substitution appears to be roughly comparable to the world averages, as reported in the GNR data. For 2006, the average clinker factor for the GNR respondents was about 78%, with most companies in the 70-85% range.[36] For Mexico in 2006, CEMEX reported that for its 15 plants, the weighted average clinker factor was 78 .4 percent.[37]

Use of High Volume Fly Ash (HVFA)

The burning of coal to produce electricity produces not only carbon dioxide and heat, but it also produces particulates in the form of HVFA and bottom ash. Bottom ash is what

[36] WBCSD, 2006, GNR Reporting Project, *Table 339: Clinker to cement ratio*, http://www.wbcsdcement.org/gnr-2008/world/GNR-Indicator_339-world-2006.html.

[37] CDM Project Design Document, 2007. "Project 1356: Reducing the Average Clinker Content in Cement at CEMEX Mexico Operations" and associated materials, available at http://cdm.unfccc.int/Projects/DB/SGS-UKL1190380419.97/view.

remains of the burned fuel, and fly ash is the smaller particles that become airborne during the burning process and are typically collected in dust collectors.

The current usage of fly ash worldwide is small, however there are many co-benefits to fly ash blending. HVFA-blended cement properties include: increased strength; reduced heat of hydration, which leads to less cracking; protection against corrosion; and improved workability. The primary drawback to fly ash cement is the slower strength gain, which under certain circumstances may take weeks to achieve full tensile strength as opposed to days or even hours for other cements.

High Volume Fly Ash does have its limitations. The iron content of HVFA must be monitored. When the iron content of fly ash from coal is higher than about 8%, the amount that can be used is limited. High sulfur coals are more likely to be higher in iron, given that iron and sulfur content in coal are usually proportional. Conversely, fly ash from coal with low sulfur content, and therefore low iron content, can be used more widely as a cement additive.[38]

If coal use decreases in response to a carbon price, the availability of HVFA would also decrease dramatically. HVFA should therefore be characterized as a short-term solution with significant climate change benefits, but it should not be incorporated into a long-term development strategy.

In Mexico, only a small quantity of fly ash is available. The supply that is available is of very poor quality and is therefore not being used by the cement industry[39]

Use of Natural Pozzolans

Mexico also has indigenous supplies of pozzolan (a volcanic rock), which has become a traditional substitute for clinker in Mexico. Pozzolans are mainly concentrated in the center of the country, in Estado de Mexico, Puebla, Guanajuato, Hidalgo and Guerrero. Other states in the north, such as Chihuahua and Durango, also have deposits. According to our consultation with *Agregados del Centro*, a pozzolan producer in Hidalgo, current estimates of pozzolan deposits in the state amount to 35 million tons. Of course, these reserves may change over time, with additional exploration and development, changing market conditions, and depletion from production.

Pozzolan is a siliceous material that reacts with calcium hydroxide to create cementitious compounds in the presence of water. It is an effective additive in blended cements and has the co-benefit of forming stronger concrete that is especially resistant to corrosion. However, similar to fly ash, pozzolan cements take longer to come to full strength. In

[38] Roewer, J., and Klein, D. E., 2006, "Estimating GHG Savings from Use of Coal Combustion Products: Methodology and Results for 2000-2005," part of the comments submitted by the Utility Solid Waste Activities Group in response to the Department of Energy's Revised General Guidelines and Draft Technical Guidelines for the §1605(b) Voluntary Reporting of Greenhouse Gases Program, November.

[39] Malhotra, V. M., and Hemmings, R, T,, 1995, "Blended Cements in North America - A Review," *Cement and Concrete Composites*, 17.

addition, they also have a high water demand and poor workability retention.[40] The formulation of more complex blends of cements, at times blending up to three or four different cementitious materials, can overcome these difficulties.

In many cases, however, cement plants do not have a ready source of pozzolans in their vicinity. Access to other substitutes like fly ash and blast furnace slag can also be very limited and location-specific.[41] In some cases, investments in infrastructure are needed before the materials can be easily accessed. If transportation costs and the associated emissions are factored in, blending with pozzolans might not be cost-effective.

Mexico led the production of blended cements in North America in 1995, with 60% of the production being blended cements from natural pozzolans.[42]

Use of Blast Furnace Slag

Blast furnace slag is a residue of pig iron production similar to sand. It has properties similar to clinker and, under certain conditions, can be used as a clinker substitute. Slag is comprised of silicates, alumina-silicates, and calcium-alumina-silicates. Unlike HVFA, slag replaces the raw material limestone (not clinker), and it adds burnability to the material, thus decreasing the emissions from limestone calcification. Slag cement reduces the energy use for concrete by about 40% compared to ordinary Portland cement.[43] In addition, utilizing slag in blended cement reduces the risk of local contamination of groundwater or soil from improper or inadequate disposal of the slag.

The cost of slag and the transportation of slag can be prohibitive, which presents the foremost barrier to the use of blast furnace slag in cement production. Mexico used to produce relatively small amounts of blended cement incorporating granulated slag, but environmental concerns resulted in closing of the blast furnace operation in Monterrey, near many cement plants, which in turn eliminated the availability of granulated blast furnace slag.[44]

No silica fume is available in Mexico, though silica fume is also a common blending agent.

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[40] Damtoft, J. S., Lukasik, J., Herfort, D., Sorrentino, D., and Gartner, E. M., 2007, "Sustainable Development and Climate Change Initiatives," *Cement and Concrete Research*.

[41] Fly ash from coal-fired power stations can be an excellent clinker substitute only if the power plants reach and maintain the necessary combustion efficiency. In addition, the quality of local slag can be improved if highly capital-intensive modern quenchers are installed,

[42] Malhotra, V. M., and Hemmings, R. T., 1995, "Blended Cements in North America - A Review," *Cement and Concrete Composites*, 17.

[43] Ehrenberg, A., 2002, "CO_2 Emissions and Energy Consumption of Granulated Blast Furnace Slag," EUROSLAG publication, 2, p. 151-166.

[44] Malhotra, V. M., and Hemmings, R. T., 1995, "Blended Cements in North America - A Review," *Cement and Concrete Composites*, 17.

Blending Considerations

As discussed above, one of the potential barriers to increased use of blending materials in cement production is the associated costs. This includes both the up-front capital costs, as well as ongoing annual expenses. The one-time costs to initiate the production of blended cements include material storage and handling facilities for the blending agents, while the annual costs include costs associated with obtaining the blending materials themselves, operations and maintenance costs (e.g., of handling and storage equipment), and costs for transportation of the blending materials. In Mexico, a one-time cost of about $1.5 million is believed be required to initiate blending, based upon the average cost reported by CEMEX.[45] However, the annual costs will vary with the type of blending materials under consideration and the location of any given cement plant with respect to the source of these materials.

Cost savings associated with blending are associated with a decrease in clinker production per ton of cement produced. This means less limestone and fuel consumption are needed per ton of cement, but electricity use generally increases, as the blending materials can require more grinding and processing than raw clinker. Depending on fuel prices, these cost savings may be to offset the extra costs associated with obtaining and preparing the blending materials.

However, fly ash, slag, and other blending materials are generally low-value materials on a per-ton basis. As such, their delivered cost is very sensitive to transport distance, and long-distance transport is often uneconomic. Because there are relatively few coal-fired power plants and iron blast furnaces near cement facilities, Mexico may be less well-suited for this mitigation action.

Even if clinker substitutes are locally available, other barriers may limit their usefulness. Different applications of cement and concrete require different qualities, which are often determined by specific blending recipes. Documented assessment of substitution material properties is needed to understand and communicate which substitutes are best for any intended application. For example, cement standards allow up to 95% blast furnace slag in some cements. However, this type of cement has low early-stage strength. These cements are only suitable for very special applications, and their use depends on their availability. It would be valuable to develop and cross-reference roadmaps for different industries which are linked to the cement industry by the production of clinker substitutes. This will enable forecasting of the effects of mitigation technologies in one industry impacting mitigation potential in other industries.[46]

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[45] CDM Project Design Document, 2007. "Project 1356: Reducing the Average Clinker Content in Cement at CEMEX Mexico Operations" and associated materials, available at http://cdm.unfccc.int/Projects/DB/SGS-UKL1190380419.97/view.

[46] WBCSD/IEA, 2009, *Cement Technology Roadmap 2009: Carbon Emissions Reductions up to 2050*, https://www.iea.org/papers/2009/Cement_Roadmap.pdf, p. 13.

This concern is also the reason that the cement industry in Mexico has emphasized that they can not produce cements with lower clinker fractions without having a demand for such products. Standards exist in Mexico that specify a range of acceptable cement blending levels for different applications. However, for a variety of reasons, the construction industry will often choose to use cements with minimal allowed blending. Therefore, to successfully implement a program for increased blending in cement, the sectors that use these cements must also be involved, and the Mexican government must incentivize the use of these higher blends.

Longer term, additional materials may be able to reduce or even replace traditional cement-making technologies. A number of low-carbon or even carbon-negative cements are currently being developed by start-up companies expecting to build pilot plants in the next year or two. The cements, being developed by companies such as Novacem, Calera, and Calix, are based on alternative kiln feeds using less carbonate material, or make cement using processes more amenable to CCS, or even use the CO_2 as a feedstock.[47]

The mechanical properties of these new types of cements appear to be similar to those of Portland cement. However, these new processes are still at the development stage. They are currently neither proven to be economically viable nor tested at scale for their long-term suitability. Nor have their products been accepted in the construction industry, where strong material and building standards exist. As and when the first production plants come on stream, initial applications are likely to be limited and apply to niche markets, pending widespread availability and customer acceptance.

It is therefore not known whether these new cements can have an impact on the future cement industry. In the long term, they may offer opportunities to reduce the CO_2 intensity of cement production, and their progress should be followed carefully and potentially supported by governments and industry.

Carbon Capture and Storage (CCS)

Carbon Capture and Storage (CCS) is a new technology that is not yet proven at the industrial scale in cement production but is potentially promising. Here, CO_2 is captured as it is emitted, compressed to a liquid, and then transported in pipelines to be permanently stored deep underground. Therefore, energy consumption will obviously increase if CCS is employed.

In the cement industry, CO_2 is emitted from fuel combustion and from limestone calcination in the kiln. These two CO_2 sources may require industry-specific capture techniques that are low-cost and efficient, and literature studies show that some capture technologies seem more appropriate for cement kilns than others.[48]

[47] WBCSD/IEA, 2009, *Cement Technology Roadmap 2009: Carbon Emissions Reductions up to 2050*, https://www.iea.org/papers/2009/Cement_Roadmap.pdf, p. 5.

[48] WBCSD/IEA, 2009, *Cement Technology Roadmap 2009: Carbon Emissions Reductions up to 2050*, https://www.iea.org/papers/2009/Cement_Roadmap.pdf, p. 14.

R&D for CO_2 capture from cement plants falls into three primary categories:

1. ***Pre-combustion technologies.*** Separating CO_2 from the other exhaust gases is one of the most costly steps in carbon capture and storage. For many emission sources, capturing the CO_2 pre-combustion is a promising technological path. However, for cement plants, where most of the emissions originate from the calcination of the limestone, pre-combustion capture of the CO_2 emissions from the fuel would still leave most of the overall emissions uncaptured. Accordingly, pre-combustion technologies are generally not viewed as attractive pathways for cement emissions mitigation.
2. ***Post-combustion technologies.*** Post-combustion technologies refer to a set of approaches that seek to capture the end-of-pipe CO_2 emissions from fuel combustion and limestone calcination. They generally would not require fundamental changes in the clinker production process, and as such could be considered for retrofit as well as new facilities. Research is most advanced on chemical absorption processes, although membrane technologies also show promise for the relatively high CO_2 concentrations from cement kilns.
3. ***Oxyfuel technologies.*** If oxygen were to be used instead of air in the combustion process, a relatively pure stream of CO_2 would be available for capture. This is a very different technology than that currently employed in cement kilns, and as such, extensive research would still be needed to understand and perfect the technology. Oxyfuel technology is now being demonstrated at small-scale power plants, and these results may prove helpful for evaluating designs for future cement kilns.

Of course, the capture of CO_2 is a major, but not the only, component of carbon capture and storage. Once captured, CO_2 must also be transported and either stored in a permanent setting or used productively in a long-lived application. These additional stages will need appropriate technologies, infrastructure, legal and regulatory frameworks, and procedures for monitoring, reporting, and verification (MRV). These additional stages are applicable not only to CO_2 captured from cement kilns, but to CO_2 capture broadly.

Summary: Applicability of Four Mitigation Pathways for Mexico

This section has looked at the four primary mitigation pathways that the cement industry can use to reduce CO_2 emissions: (1) improving thermal and electric efficiency, (2) increasing use of alternative fuels, (3) clinker and cement substitution, and (4) carbon capture and storage. These were described as pathways that are broadly applicable to the cement industry worldwide, recognizing that country-specific conditions will make some of these measures more or less applicable to a specific country or company.

In Mexico's case, the prevalence of modern facilities and high degree of energy efficiency offer fewer opportunities going forward for further improvements in energy use. The more promising areas for CO_2 reductions would appear to be in increasing the use of alternative fuels and increasing clinker and cement substitution. Carbon capture and storage (CCS) is a potentially promising future technology but is not yet proven for the cement industry, either technically or economically.

This initial identification of alternative fuels and clinker substitution as promising areas for CO_2 mitigation is based upon international comparisons and with discussions with the industry in Mexico. The extent to which this promise can be realized will depend upon a closer examination of the local availability and cost of alternative fuels and blending materials, and also upon the institutional and technical viability of their use.

IV. MEASUREMENT, REPORTING, AND VERIFICATION (MRV) IN CEMENT

This section examines MRV issues specifically related to the cement industry.[49] In Mexico, cement facilities report their GHG emissions to at least two programs within SEMARNAT: the Registro de Emisiones y Transferencia de Contaminantes (RETC) and the Programs GEI.[50] Either of these could serve as the basis for an official MRV system for Mexico's cement sector.

The RETC requires all industrial facilities to report their releases of a variety of air, water and other pollutants. Although their emissions are not regulated, GHGs are included in these reports. However, the reports are not currently subject to verification, so the accuracy of the reported emissions levels is uncertain. In addition, facilities are allowed to choose from a range of methodologies to estimate their GHG emissions, so consistency of the reports among different facilities within the same sector is also questionable.

Under the Programa GEI, which is voluntary, companies (rather than individual plants) report their emissions of GHGs, and all but one of the cement companies in Mexico currently participate in this program. Here, a consistent methodology, developed by the the WBCSD and WRI Greenhouse Gas Protocol is used by all companies.[51]

Globally, a variety of protocols have been developed for measuring and reporting cement-sector GHG emissions. Mexico could decide to adopt one of these protocols, rather than either of those mentioned above. Three such protocols are described and compared below, followed by a discussion of the systems and uses for the collected data.

GHG Emissions Reporting Protocols

A number of international procedures and protocols have been developed for reporting of emissions in the cement sector. These procedures and protocols have evolved pursuant to broader international objectives in GHG reporting, and reflect conditions specific to the cement sector and variations across countries and companies. Below are discussed three of the key reporting procedures: the IPCC Emission Reporting Guidelines for the Cement Sector, the CSI Cement CO_2 Protocol, and the U.S. EPA's Mandatory GHG Reporting for the Cement Industry.

IPCC Emission Reporting Guidelines for the Cement Sector

In 1996, the Intergovernmental Panel on Climate Change (IPCC) produced detailed guidelines for countries for the reporting of national emission inventories by Annex 1 countries (advanced economies) under the United Nations Framework Convention on Climate Change (UNFCCC). Those guidelines have been revised over time and

[49] A separate report under this project takes a broader look at MRV issues, including MRV for national inventory reporting, for fast-start finance, and for NAMAs outside the cement and iron and steel sectors.
[50] See www.geimexico.org/.
[51] See www.ghgprotocol.org/.

supplemented by "Good Practice" guidance. In 2006, the IPCC issued a revised set of guidelines that incorporated all previous revisions and the good practice guidance.[52]

The 2006 IPCC Guidelines generally provide advice on estimation methods at three levels of detail, from Tier 1 (the default method) to Tier 3 (the most detailed method). A brief summary of the procedures for emission reporting by the cement sector is as follows:

- ***Tier 1 Method: Estimating clinker production through use of cement production data.*** Using a fixed cement-based emission factor to calculate CO_2 emissions directly from cement production is not consistent with good practice. Instead, in the absence of data on carbonate inputs or national clinker production data, cement production data may be used to estimate clinker production by taking into account the amounts and types of cement produced and their clinker contents and by including a correction for clinker imports and exports. Accounting for imports and exports of clinker is an important factor in the estimation of emissions from this source. An emission factor for clinker is then applied and the CO_2 emissions are calculated.
- ***Tier 2 Method: Use of Clinker Production Data.*** If detailed and complete data (including weights and composition) for carbonate(s) consumed in clinker production are not available (Tier 3), or if a rigorous Tier 3 approach is otherwise deemed impractical, it is good practice to use aggregated plant or national clinker production data and data on the CaO content in clinker, expressed as an emission factor. Embedded in the Tier 2 methodology are certain assumptions that most of the cement requires Portland cement clinker, that clinker compositions are relatively consistent and use $CaCO_3$ as the main material source, and that other factors apply.
- ***Tier 3 Method: Use of carbonates input data.*** Tier 3 is based on the collection of disaggregated data on the types (compositions) and quantities of carbonate(s) consumed to produce clinker, as well as the respective emission factor(s) of the carbonate(s) consumed. Emissions are then calculated using formulas for (1) emissions from carbonates, (2) emissions from uncalcined cement kiln dust (CKD) not recycled into the kiln, and (3) emissions from carbon-bearing non-fuel materials. The Tier 3 approach will likely only be practical for individual plants and countries that have access to detailed plant-level data on the carbonate raw materials.

Properly implemented, all tiers are intended to provide unbiased estimates, and accuracy and precision should, in general, improve from Tier 1 to Tier 3. The provision of different tiers enables inventory compilers to use methods consistent with their resources and to focus their efforts on those categories of emissions and removals that contribute most significantly to national emission totals and trends.

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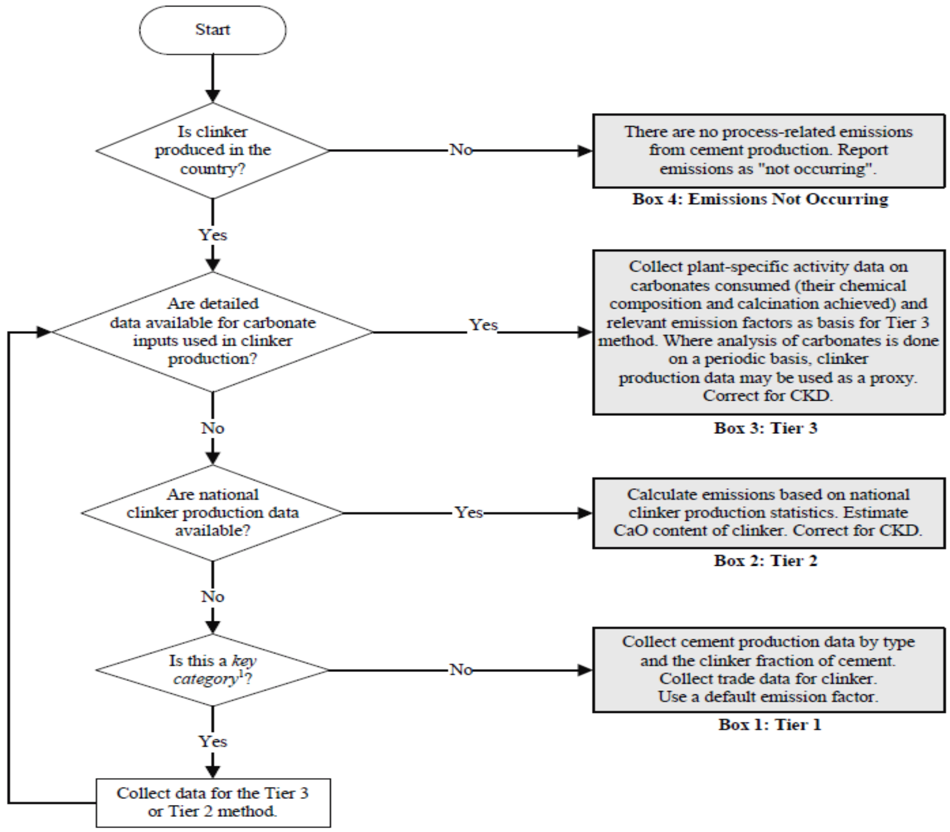
[52] IPCC, 2006, *2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 3: Industrial Processes and Product Use, Chapter 2: Mineral Industry Emissions*, http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_2_Ch2_Mineral_Industry.pdf.

The IPCC guidelines include a decision tree describing good practice in choosing the most appropriate method based on national circumstances. As suggested in this decision tree, shown in Figure 6 below, the Tier 3 Method is most likely the appropriate method for Mexico's cement industry.

Figure 6. The IPCC Decision Tree for Estimating CO_2 Emissions from Cement



The CSI Cement CO_2 Protocol

The Cement Sustainability Initiative (CSI) of the World Business Council for Sustainable Development (WBCSD) has developed a protocol for CO_2 emissions reporting by the cement sector. This protocol is used in the voluntary Programa GEI in Mexico, as discussed in a later section.

In 2001, the CSI companies agreed on a methodology for calculating and reporting CO_2 emissions: the Cement CO_2 Protocol. In June 2005, a revised edition of the Cement CO_2 Protocol incorporated changes based on extensive practical application of the protocol by many cement companies worldwide. It also aligned the Cement CO_2 Protocol with the 2004 revised edition of the WRI/WBCSD GHG Reporting Protocol. [53]

[53] WBCSD, 2005, *CO_2 Accounting and Reporting Standard for the Cement Industry,* version 2.0, June, http://www.wbcsd.org/web/publications/cement-tf1.pdf.

This protocol is intended as a tool for cement companies worldwide. It provides a harmonized methodology for calculating CO_2 emissions, with a view to reporting these emissions for various purposes. It addresses all of the direct and the main indirect sources of CO_2 emissions related to the cement manufacturing process in absolute as well as specific or unit-based terms. The protocol's two main elements are the guidance document and an Excel spreadsheet tool to help cement companies prepare their CO_2 inventories.

The basic calculation methods used in the CSI protocol are compatible with the latest guidelines for national greenhouse gas inventories issued by the IPCC, and with the revised WRI/WBCSD Protocol. Default emission factors suggested in these documents are used, except where more recent, industry-specific data has become available. This allows cement companies to report their CO_2 emissions to national governments in accordance with IPCC requirements. In addition, the protocol was designed to be a flexible tool that facilitates reporting under various schemes, such as the European Greenhouse Gas Emissions Trading System, the U.S. EPA's Climate Leaders Program, and other similar initiatives.

The CSI protocol describes organizational boundaries to define which parts of an organization are to be covered by an inventory. Cement companies using the protocol are to include the following types of activities, to the extent that they control or own the respective installations:

- Clinker production, including raw material quarrying;
- Grinding of clinker, additives and cement substitutes, such as slag, both in integrated cement plants and stand-alone grinding stations; and
- Fly ash beneficiation.

The inventory reporting covers both direct emissions and indirect emissions. Direct emissions are emissions from sources that are owned or controlled by the reporting entity, which for cement plants typically include the following sources:

- Calcination of carbonates, and combustion of organic carbon contained in raw materials;
- Combustion of conventional fossil kiln fuels;
- Combustion of alternative fossil kiln fuels (also called fossil AF or fossil wastes);
- Combustion of biomass kiln fuels (including biomass wastes);
- Combustion of non-kiln fuels;
- Combustion of the carbon contained in wastewater.

Indirect emissions result from the activities of the reporting company but occur at sources owned or controlled by another company. For a cement company, the primary source of indirect emissions will be from the generation of grid electricity used by the cement plant.

U.S. EPA's Mandatory GHG Reporting for the Cement Industry

The U.S. Environmental Protection Agency (EPA) began a program of mandatory reporting of GHG emissions in many industrial sectors in 2010. In the cement sector, the EPA requires reporting by each cement kiln. EPA had considered reporting thresholds of 1,000 to 100,000 metric tons of carbon dioxide (CO_2) emissions, but recognizing that only one plant emits less than the 100,000 tons/year level, EPA decided to require reporting by all plants.

The EPA requires monthly reports on the production of clinker and cement at each kiln.[54] In calculating CO_2 emissions, the EPA requires kilns to use a "tier 4 methodology" – a continuous emission monitoring system (CEMS) – if available. The CEMS would measure and report both calcination and fuel combustion emissions. If a CEMS is not available, separate methods are used to calculate the carbon dioxide emissions from clinker production and from the consumption of raw materials.

Emissions from the production of clinker are calculated from monthly clinker output and:

- a monthly, kiln-specific clinker emission factor,
- the kiln's measured monthly total and non-calcined calcium oxide and magnesium oxide weight-fractions of the clinker (used to compute the above emission factor),
- quarterly measurements of cement kiln dust (CKD) not recycled to the kiln,
- a quarterly kiln-specific emission factor for non-recycled CKD, and
- the kiln's quarterly total and non-calcined calcium oxide and magnesium oxide weight-fractions of the non-recycled CKD (specifying the methods used to determine the non-calcined portions).

Emissions from the consumption of raw materials are calculated annually from the amount consumed of each material and its organic carbon content (either measured or using a default value of 0.2%).

In devising its reporting rule, the EPA considered the CSI reporting protocol as well as the 2006 IPCC Guidelines, U.S. inventory, Department of Energy regulations, California Air Resources Board (CARB) mandatory reporting, EPA's Climate Leaders program, and the EU ETS. EPA chose a rule that was close to the cement industry's voluntary CSI protocol. One key difference is that the CSI Cement CO_2 Protocol allows default emission factors where detailed plant-specific emission factors are not available. EPA's reporting rule requires the plant-specific detail, as this was considered to be existing practice at U.S. facilities.

The EPA's rule also differs from the Cement CO_2 Protocol in its specification of methods for calculating CaO, Mg, and clinker weight. The EPA selected its methodology based

[54] U.S. EPA, 2009, *Mandatory Reporting of Greenhouse Gases; Final Rule*, 40 CFR Parts 86, 87, 89 et al., published in the Federal Register on October 30, http://www.regulations.gov/#!documentDetail;D=EPA-HQ-OAR-2008-0508-2278.

on techniques that are common in the industry (ASTM C114).[55] The EPA insists that standardization of the measurement procedures is essential to ensure consistency and comparability of the data from different kilns.

Systems and Uses for Collected Data

Under the CSI, efforts to assemble a global database on cement CO_2 emissions have been initiated. These data are being used to characterize regional and industry-wide trends in performance, and have been proposed as the basis for MRV of emission reductions for several types of cement projects under the Clean Development Mechanism (CDM).

"Getting the Numbers Right": A Global Cement Database on CO_2 and Energy Information

Recognizing the importance of data that are consistent and of high quality, the Cement Sustainability Initiative in 2006 initiated the "Getting the Numbers Right" (GNR) system. Its objective is to obtain and provide transparent and verifiable data for CO_2 and energy performance of clinker and cement production at global and regional levels across cement companies worldwide.

The CSI published its first full GNR report in June 2009, covering the period 1990 to 2006.[56] The system includes information from 844 cement installations worldwide, covering over 73% of cement production in Kyoto Protocol Annex 1 countries. However, coverage in non-Annex 1 countries is only around 20%, due to the absence of many domestic companies, especially in China. At the time of this report, all WBCSD CSI members participate in GNR by submitting CO_2 and energy performance data. Additionally, CEMBUREAU, the European cement association participates in GNR and has adopted the WBCSD/CSI CO_2 Protocol. It has collected information from non-CSI cement plants, ensuring nearly full participation of all cement installations in Europe. Figure 7 shows the regional coverage of cement production in the GNR database, based on the 2006 information.

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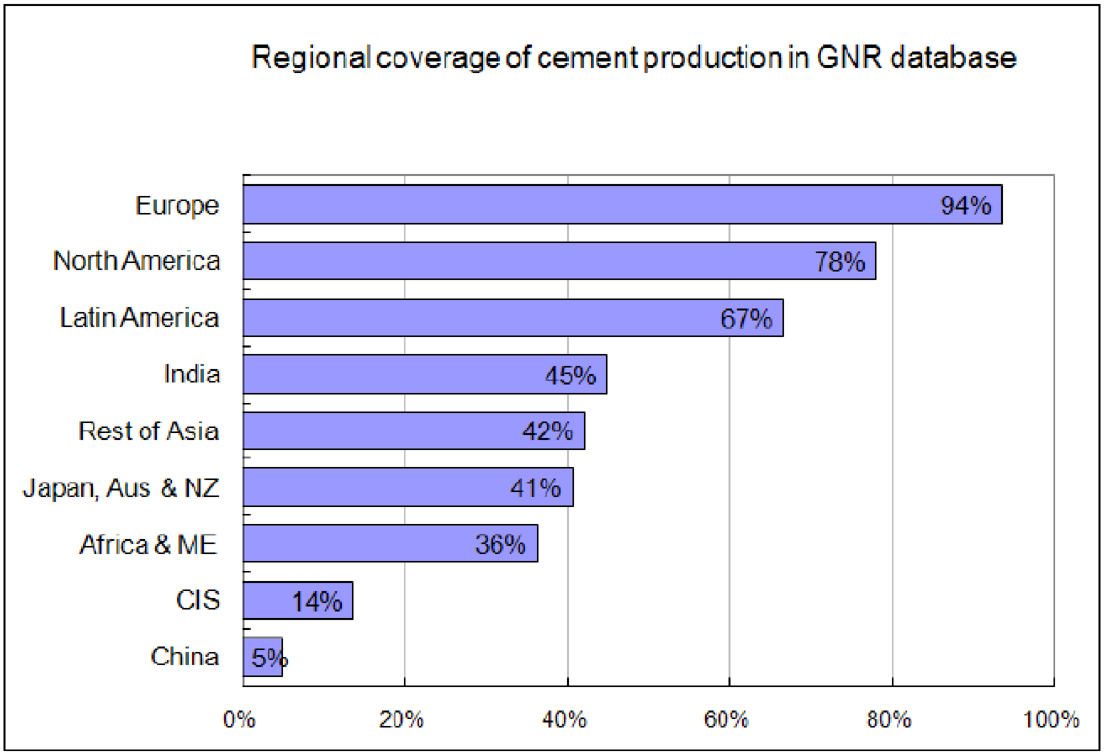
[55] American National Standards Institute, *ASTM C114-10A: Standard Test Methods for Chemical Analysis of Hydraulic Cement*, http://webstore.ansi.org/RecordDetail.aspx?sku=ASTM+C114-10a.

[56] WBCSD, 2009, *Cement Industry Energy and CO_2 Performance: Getting the Numbers Right,* June, http://www.wbcsdcement.org/pdf/CSI%20GNR%20Report%20final%2018%206%2009.pdf.

Figure 7. Regional Coverage of Cement Production in the GNR Database, 2006



In July 2010, the CSI released updated figures for the GNR database.[57] The latest data covers cement production in 2008,[58] using data made available by 46 companies, with over 900 production facilities globally. The key findings reported by CSI include:

- The cement industry continues to reduce CO_2 emissions intensity per tonne of cement produced. In 2008, the companies voluntarily reporting to the GNR database emitted on average 646 kg net CO_2 per tonne of cementitious material (the equivalent of 665 kg gross CO_2 per tonne of cementitious material, when biomass fuels are accounted at their gross rather than their net carbon content).

- This is a 3.8% reduction in net CO_2 emissions since 2005 and 14.3% reduction since 1990, equivalent to over 90 million tonnes of CO_2 abated in 2008 compared to 1990 performance. The consolidated absolute CO_2 emissions of all GNR participants also decreased year-on-year for the first time, from 596 million tonnes in 2007 to 577 million tonnes in 2008, reflecting the impact of the economic downturn and accompanying slowdown in construction activity. The companies that report to the GNR database cover close to two-thirds of cement production outside of China and approximately one third of global production.

[57] Hunziker, R., 2010, "New Cement Industry Figures on CO_2 and Energy Performance Show Reduction in Emissions Intensity," press release from Roland Hunziker, Assistant Project Manager, CSI, July 13.

[58] There is a one-year embargo on data release to comply with anti-trust regulations.

- The lowest net CO_2 emissions per tonne of cementititious material, reported by region in the GNR system, are 560 kg CO_2 in South America, followed by 606 kg in Europe and 613 kg in India.
- There are significant regional differences with regards to the main levers for CO_2 reductions in cement production: thermal energy efficiency, use of alternative fuels and biomass, and clinker substitution.
    - When it comes to thermal efficiency, plants in India are the most efficient, with approximately 3100 MJ per tonne clinker. Because of the dry raw materials used and the modern technology deployed, Indian plants are 10-20% more efficient than plants in other regions and are about 40% more efficient than old wet-process technology.
    - The use of alternative fuels to replace conventional fossil fuels is most advanced in Europe, where 17.5% of thermal energy is sourced from fossil waste (up from 15.5% in 2007). Including biomass, Europe substitutes more than one-fifth of conventional fossil fuels with fossil waste and biomass (22.3%).
    - Brazil is the leader in the use of biomass as a substitute fuel, with 12% of total thermal energy generated. Adding 9% fossil waste, Brazil also replaces more than one fifth of fossil fuels with alternative fuels.
    - New data available this year gives a detailed breakdown by region of the use of various clinker substitutes. The highest substitution rates are reported from South America, mainly locally available slag in Brazil and pozzolans in the rest of South America, followed by limestone. China, Europe and India also substitute more than 25% of clinker in cement production.
    - In China, CO_2 emissions reductions are mainly driven by clinker substitution and a strong increase in thermal efficiency, which is a consequence of replacing old wet and shaft kilns with highly efficient state-of-the-art technology. Specific emissions of the installations captured by the GNR-database (multinational companies operating in China) are comparable to those found in Europe. Alternative fuel and biomass use are still very low in China, indicating a further potential for emissions reductions in the future.

Standard web-based reports using the GNR database are available at www.wbcsdcement.org/co2data. Apart from the global and regional 2008 data, information is now also available for the following countries: Austria, Brazil, Canada, China, Czech Republic, France, Germany, India, Italy, Spain, the UK, and the US.

CSI Protocol and GNR Data in the CDM

The increasing participation in the Cement Sustainability Initiative and the growing coverage of the GNR database make it a logical starting point for MRV activities for future mitigation efforts, in Mexico and elsewhere. Mexico's cement producers include leading companies in the CSI, and they are already reporting their emissions into the GNR database.

Under the Clean Development Mechanism (CDM), a methodology was proposed for measuring emission reductions in cement production facilities, where the CSI Protocol and GNR data would be used in setting benchmarks and measuring GHG reductions in clinker and cement production in new and existing plants.

The proposed methodology was titled "Emission reductions in the cement production facilities of Holcim Ecuador S.A." and was submitted on April 1, 2009.[59] In June 2009, the CDM Meth Panel replied to the proposed methodology with a series of questions and issues to be addressed.[60] The issues raised include, among others:

- ***Confidentiality and proprietary data.*** It was noted that the CSI GNR database is a third-party proprietary instrument, and that at present, the access is restricted and the data is not publicly available. However, the methodology indicates that some data needed to calculate baseline emissions and assess additionality would be made publicly available.
- ***Verifiability.*** The Methodology Panel noted that it was very clearly described how the data reported by companies to the database administrator is validated by independent entities.
- ***Coverage.*** The Methodology Panel noted that the CSI covered only 31% of global cement production in 2006, with data obtained mostly from Europe, North America, Latin America and India. Asia and China seem to be underrepresented in the database. With this data gap, coverage may not be adequate to establish a benchmark for some regions.

These and other issues raised by the CDM Methodology Panel were addressed in a document dated October 19, 2009.[61] There, the applicants defend the methodology and data quality and describe approaches to meeting the CDM Executive Board's concerns while maintaining the necessary controls for confidentiality and antitrust concerns.

These issues – still unresolved – highlight an essential conflict between data quality and availability. On one hand, the GNR database is arguably the most complete and highest-quality set of data available for the global cement industry. However, as a condition to assembling this data, very strict controls were required to prevent disclosure of company-sensitive data, the release of which could pose serious issues related to competitiveness and antitrust. These controls include third-party independent administration of the database, data disclosure only at an aggregate level that does not allow company or plant-specific data to be deduced, and a time lag in data collection and publication (the 2009 GNR report used data from 2006).

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[59] Holcim Ecuador, 2009, *Emission reductions in the cement production facilities of Holcim Ecuador S.A.*, Apr 1, http://cdm.unfccc.int/UserManagement/FileStorage/NAH2ZJ5CMOV8BX6LP74F3IERTY0GS9.

[60] CDM Meth Panel, *CDM: Proposed New Methodology, Meth Panel recommendation to the Executive Board*, June 26, available at http://cdm.unfccc.int/UserManagement/FileStorage/GYNQ6J5R843IXF9WZV0CMUPHE7O1LT.

[61] http://cdm.unfccc.int/UserManagement/FileStorage/9F458E1NKHGJRTV6AZM2O7UPSQWXL3.

V. BARRIERS TO IMPLEMENTATION:

Input Supply Barriers

Many of the mitigation options analyzed in this study have associated supply issues. Specifically, there are a number of possible supply chain barriers related to the availability of the different types of alternative fuels and the materials that are suitable for use in blended cement.

Access to fly ash and blast furnace slag, which are often used in blended cements, is very limited and highly location specific in Mexico. In addition, research may be needed to improve upon the blending process so that the clinker fraction can be decreased without compromising the structural integrity of the final cement product. Joint research efforts by industry and government could provide valuable results in this area that would allow increased use of blending materials and a related reduction in emissions associated with the production of clinker.

Several of the materials that can be used as alternative fuels, such as plastics, sewage sludge, MSW, and wood waste, require unique materials handling systems to make them accessible to the cement industry. Each type of material needs a system of collection, initial processing, delivery, and storage that is tailored specifically for that material. For example, before sewage sludge can be used as a fuel, it must first be treated for pathogens, then dried, transported to a manufacturer's facility, and stored in a manner that prevents re-hydration. With the exception of providing on-site storage facilities, these activities are not likely to be undertaken by cement manufacturers. Preparing and handling sewage sludge requires expertise and equipment that is not available to the typical cement plant. Likewise, for waste plastics to be used as a fuel by cement manufacturers the materials must first be collected from initial users (households and businesses), sorted to remove materials, such as Polyvinyl Chloride (PVC), that contain vinyl chlorine – a known carcinogen – and finally shredded to produce a material that can be fed into a cement kiln. Again the activities, equipment, and expertise needed to convert waste plastics into a viable fuel source for cement kilns are quite different from those that are accessible at the typical cement plant. These two examples illustrate the need for upstream materials handling capabilities by entities that are most likely not members of the cement sector.

Another form of supply constraint relates to the location specific nature of some types of alternative fuels. For example, used tires are really only a cost-effective alternative fuel in areas where a supply of scrap tires is found in close proximity to the plants that will use them. In Mexico, the main region where this is true is in the north near the U.S. border. For cement plants in central and especially in southern areas of Mexico, access to this potential fuel source is much more limited.

In addition to alternative fuel supply chain barriers, there are also issues associated with the quality of cement produced using alternative fuels. For example, scrap tires often contain significant amounts of zinc in the steel belts used in radial tires. If the belts are not removed during shredding, zinc can be absorbed by clinker during processing. If too much zinc is absorbed cement made from zinc contaminated clinker will harden too quickly and would not be suitable for most uses.

Informational Barriers

The cement industry's adoption of alternative fuels could be further stimulated by access to some basic research into the effects of using alternative fuels in the clinker production process. Determining how various substances found in alternative fuels will ultimately affect the quality of the final product and/or continuing operations at facilities that adopt alternative fuels, is a complex process that requires expert knowledge about the properties of the materials that comprise alternative fuels. This type of expertise and the associated research efforts are not always readily available to the cement industry. Limited access to sound information on the impacts of alternative fuel use on product quality acts as a barrier to more widespread use of these substances. As noted above, using tires as an energy source brings with it a risk that the clinker produced will be adversely affected by the absorption of zinc. What is not clear is the exact mix of scrap tires and other fuels that can be used without risking excessive amounts of zinc in the final product. Research is needed to understand the conditions under which tires can be safely used as a substitute for more traditional fuels.

Likewise, additional information is needed regarding the use of blending materials in producing cement. Blast furnace slag, fly ash and pozzolans are currently mixed with clinker to create blended cements. However, these materials are not available at cost-effective prices in many locations. Research is needed to identify other potential blending materials and to assess the implications of using these materials, particularly in terms of any potential effects on the quality of the final product.

Financial Barriers

There is no evidence suggesting that financial barriers are inhibiting adoption of GHG mitigation options within the cement industry *per se*. Mexico has a flexible trade policy (including NAFTA) that allows imports from Canada and the United States to enter Mexico duty-free. Moreover, all of the major cement companies operating in Mexico are well capitalized and have access to formal credit markets.

Financial barriers might however be an issue affecting the potential supply of alternative fuels. Many of the activities associated with generating a supply of alternative fuels, such as scrap tires, wood, agricultural waste, sewage sludge, etc., are best performed by firms other than the major cement producers. To the extent that it is difficult for small firms in these supply-side industries to obtain funding to purchase equipment and/or to cover other types of costs, financial barriers will limit the ability of cement producers to achieve their maximum emission reduction potential.

Regulatory Barriers

Most cement plants in Mexico are currently authorized to use scrap tires and other waste materials for fuel. However, there are some potential environmental issues associated with the burning of these materials in cement kilns. For example, cement kiln dust (CKD), which is a fine matter produced during combustion and transported by the flow of hot gases within a kiln, can contain a variety of substances that are hazardous to human health. Some examples of materials found in CKD include arsenic, dioxin, furans, lead, and chlorine. The concentrations of all of these substances can be increased by the use of some types of alternative fuels. To minimize adverse impacts on human health, regulations are used to restrict the quantity of some alternative fuels that can be burned in processing clinker. The closer that manufacturing facilities are to large population centers, the more likely it is that regulations are already in place and/or that restrictions could be tightened or implemented in the future.

Interaction of Mitigation Approaches with Other Sectors

Mitigation options for the cement or other sectors need to be developed within the context of a broader Mexican low-carbon development strategy. The PECC has articulated a set of national climate change objectives for Mexico, but a further level of specificity is needed to work out possible conflicts among mitigation policies and programs across sectors of the economy. A broad cap-and-trade program, or other approaches that would cover many economic sectors and establish a common carbon price, would facilitate cost-effective mitigation activities that span and implicitly take account of interactions among many sectors.

But unless and until such broad, multi-sector market-based approaches can be implemented, the policies or programs designed for one sector need to take account of interactive effects with other economic sectors. Important industries in Mexico, including cement and steel, are energy-intensive and trade-exposed. Additionally, Mexico is rich in hydrocarbons, the preferred form of fuel supplied by the government-owned oil company, PEMEX. Energy markets link all of these sectors to each other, as well as to the government and other sectors of the economy. Because of these linkages, different requirements, incentives, and/or carbon price signals within an economy can cause shifts and possible disruptions in fuel market balances which could lead to unanticipated and undesirable economic and environmental effects.

Potential Fuel Market Impacts

Fuel markets, especially some of the fossil fuel markets, are highly competitive, broadly traded, and fungible on a regional or global basis. In such integrated markets, fuel choice decisions at one facility will have effects on the supply and demand situation at others. And for state-owned oil companies, these dynamics can also have revenue implications.

Mexico's cement industry provides an illustration of these potential shifts. Petroleum coke obtained from PEMEX refineries is one of the key fuels used to fire kilns in

Mexico, representing over 60% of the energy mix for the cement sector in 2008.[1] Since petroleum coke is a high CO_2-emitting fossil fuel, the industry could potentially reduce its CO_2 emissions by increasing its use of alternative fuels, as well as by switching to other fossil fuels with lower carbon intensity, such as fuel oil and natural gas, and in some instances even coal.

If many cement kilns switched from petroleum coke to other fuels, PEMEX would be in the position of having to sell an additional supply pet coke on the market. With this pet coke having a relatively high sulfur content and a limited pool of potential consumers, its marketability elsewhere may be limited, resulting in downward price pressures on pet coke and possibly competing fuels. This marketability problem may be compounded by the constraints that PEMEX has faced on upgrading its oil refining operations, leaving it with outmoded refinery technologies and an inability to adjust production to meet the changing demands of the international marketplace. In other words, PEMEX may not be able to readily find new customers for the pet coke.

Should the price of pet coke fall as a result of lower consumption in the cement sector, it could in turn reduce PEMEX revenue, a major source of funding for the Mexican government. Hence, linkages can be seen among Mexico's cement sector fuel supplies, broader petroleum product markets, and government revenues. GHG mitigation policies need to be considered within this framework.

Potential GHG Leakage

"Leakage," in a GHG context, refers to increased GHG emissions in another location or sector as a result of GHG reduction activities at a particular site or in a specific sector. On a net basis, these leakage effects from activity-shifting can reduce the overall (global) GHG benefits from those achieved within the project boundaries.

Shifts in fossil fuel markets are a form of activity-shifting that could result in GHG leakage. Oil, in particular, is a globally traded and highly fungible commodity, and shifts in consumption patterns in one place may result in offsetting shifts elsewhere.

As an example, consider a cement kiln that can use either residual fuel oil or pet coke to fuel the clinker process. Residual fuel is about 173.9 lbs. CO_2 per MMBtu, whereas pet coke is higher at about 225.1. At the plant, switching from pet coke to distillate would reduce CO_2 by about 51.2 lbs. per MMBtu. As a GHG reduction measure, the plant decides to switch from pet coke to residual fuel oil. Its fuel oil consumption goes up, while its pet coke consumption goes down.

Because global oil production is not likely to change much as a result of a cement kiln's fuel-switch decision, increased fuel oil consumption at this location would exert increasing price pressure on fuel oil markets more broadly. Conversely, the reduced pet

[1] SENER, 2009, *Balance Nacional de Energía 2008.*

coke demand would reduce its market price pressures. In a perfectly fungible market, this could ultimately result in a fuel switch away from oil and to pet coke somewhere else on the planet.

Similarly, a shift from pet coke to either natural gas or coal would potentially create leakage effects. Both natural gas and coal are traded commodities, though perhaps less broadly and hence less fungible than many petroleum products. The kiln's shift to other fossil fuels will have some impact on the markets for those fuels, and the prices other customers are likely to see. Depending on what that shift is, it may result in higher or lower emissions overall.

In contrast, a shift to alternative fuels such as municipal waste is less likely to create leakage effects. Since many alternative fuel supplies are not readily marketable or traded, the alternative to these supplies being used here is likely to be non-use. But note that while the environmental leakage in this example may be minimal, the economic effects of PEMEX's loss of customers for its pet coke still remain.

The extent to which these fuel-switching leakage effects can undercut GHG mitigation efforts depends upon the fungibility of the fuels and the breadth of the market boundaries:

- As noted above, fossil fuels tend to be more fungible than many alternative fuels. With petroleum products largely being globally traded, and natural gas increasingly moving toward global markets, fossil fuel shifts at one place are increasingly likely to be offset elsewhere. With shifts from fossil fuels to alternative fuels, this is less likely.
- The tighter the market boundaries – either by geography, sector, or company – the more likely the leakage potential. If we are dealing with a "closed" system, say on a planet where all GHG sources are measured and priced, this would only be an academic question, as the carbon price would be equally weighed by all. But that's not the case here, where we are looking at a partially covered system, where some countries and/or industries are covered while others are not. If a cement plant sees a carbon price and/or an incentive for CO_2 reduction while the manufacturer down the road does not, then we could expect to see activity-shifting in fuels, with leakage effects eroding the environmental benefits.

Annex 2. Background Information for the Iron and Steel Sector NAMA

I. Introduction

Objective of this Paper

The purpose of this paper is to evaluate the GHG mitigation options in the iron and steel sector in Mexico, to lay the groundwork for Nationally Appropriate Mitigation Actions (NAMAs) in that sector, and to discuss options for measurement, reporting, and verification (MRV) of emissions abatement in the sector. This paper is one in a series prepared by the Center for Clean Air Policy for Abt Associates under an overall contract with USAID. Mexico's Ministry of Environment (SEMARNAT) has requested USAID assistance to support Mexico's efforts to develop a low-carbon development strategy through 2020 and 2030, along with associated policy instruments. The context for this work is Mexico's announced national goal of reducing greenhouse gas (GHG) emissions to 30% below business-as-usual (BAU) levels by 2020, conditional on its receipt of sufficient international financial and technical support. In addition, Mexico's Special Program on Climate Change (PECC) includes a goal of reducing per capita emissions to 2.8 tonnes[2] of CO_2e by 2050, equivalent to a reduction of total emissions to 50% of the 2000 level.

Background on Mexico's Iron and Steel Industry

The Mexican iron and steel industry produced 17.6 million tonnes (mt) of crude steel in 2007, the last full year before the economic recession. At that level, it is the third largest steel producer in the Americas, after the U.S. (98.1 mt) and Brazil (33.8 mt), and the 15th largest in the world. Mexico imports and exports a roughly comparable amount of steel – between 3 and 4 mt/year, with higher value steel products being exported, mainly to the U.S.

Mexico's iron and steel industry began with the construction of the first integrated steel plant in 1900 by Compania Fundidora de Fierro y Acero de Monterrey. Beginning in the 1940s, Fundidora began a major expansion, which included some of the world's earliest commercial direct reduced iron (DRI) plants. From the 1940s to the 1980s, the Mexican government sponsored the development of major state-owned companies in the sector. In 1991, the industry was privatized, trade with the United States began to grow rapidly, and minimill production expanded greatly.

Currently, Mexico's iron and steel industry is composed of 20 plants operated by several large multinational and domestic firms and numerous smaller local firms. The multinationals are Luxemburg-based ArcelorMittal, the world's largest steel company, Argentina-based Techint, with two subsidiaries (Ternium México and Tenaris Tamsa) active in Mexico, and Brazil-based Gerdau. The larger domestic producers are Altos

[2] In this paper, the term "tonne" and abbreviation "t" designate metric ton (1000 kilograms); "mt" refers to million metric tons; "ton" refers to short ton (2000 lbs).

Hornos de México S.A. (AHMSA), a private domestic firm, along with Deacero and SIMEC.

ArcelorMittal is the largest steel producer in Mexico, with a crude steel production capacity of approximately 6.7 mt at three plants. The second largest steel producer is Altos Hornos de México S.A. (AHMSA), with crude steel capacity of about 3.7 mt at a single plant. Ternium México is the third largest with three plants; Deacero is fourth with two plants. Recent production levels of the major iron and steel firms are shown in Table 1; a listing of the major steel plants is given in Appendix 1.

Table 1. Mexico's Iron and Steel Manufacturers

Crude Steel Production in thousand tonnes								
Company Name	2001	2002	2003	2004	2005	2006	2007	2008
ArcelorMittal	4,134	4,237	5,264	5,777	5,011	4,784	5,192	4,987
Altos Hornos de México, SA (AHMSA)	3,034	2,867	2,901	3,013	3,244	3,366	3,541	3,667
Ternium México	2,233	2,781	2,828	3,349	3,182	3,222	3,212	2.975
Deacero	1,030	1,166	1,108	1,221	1,448	1,568	2,126	2,189
Tenaris Tamsa	822	786	773	858	933	943	810	839
All Others (scrap-EAF minimills)	2,047	2,173	2,285	2,519	2,464	2,564	2,692	2,573
Totals	13,300	14,010	15,159	16,737	16,282	16,447	17,573	17,230

Source: CANACERO (2009).

Mexican steel plants are configured as integrated mills, which produce iron in blast furnaces (BFs) and then steel in basic oxygen furnaces (BOFs), or iron in direct-reduced iron (DRI) reactors and then steel in electric arc furnaces (EAFs). In addition, there are minimills, which produce steel from scrap steel in EAFs. Mexico, along with the rest of the world, except Ukraine, Russia and several smaller producers, has stopped using the inefficient open hearth method of steel production. Larger plants may have several processing lines; smaller plants usually have just one. In Mexico, there are three BF-BOF processing lines (at AHMSA Monclova and ArcelorMittal Las Truchas), four DRI-EAF lines (at Ternium México San Nicolas and ArcelorMittal Lazaro Cardenas) and about 20 scrap-EAF lines.

The largest plants and companies comprise a major portion of Mexico's iron and steel capacity. The largest 4 companies are the largest iron and steel producers in Mexico, accounting for 81% of Mexico's capacity – being 100% of its BF-BOF and DRI-EAF capacities and 38% of its scrap- EAF capacity.

Mexico's iron and steel sector is characterized by a particularly heavy reliance on DRI. In 2008, the DRI process accounted for 6.6% of iron production worldwide, but 57.5% of iron production in Mexico. The DRI process in Mexico and in most other countries uses natural gas as a fuel stock and reducing agent, while the more common BF process is based on coke (derived from coal).

Table 2. Production Route Profile of Major Iron and Steel Producing Countries and Regions (2008)

Country	Natural gas DRI-EAF (est.) share	Coal DRI-EAF (est.) share	Scrap-EAF (est.) share	BF-BOF share	Steel production (mt)
Mexico	30%	--	40%	29%	17.2
US	--	<0.5%	58%	42%	91.4
Canada	4%	--	37%	59%	14.8
EU27	<0.5%	--	41%	58%	198.0
Japan	--	--	25%	75%	118.7
China	--	--	9%	91%	500.3
India	10%	23%	25%	40%	57.8
Rest of World	10%	1%	34%	48%	332.3
World	3%	1%	26%	67%	1329.1

Source: CCAP estimates, based on WSA (2010) for EAF and BOF shares of steel production and DRI shares of iron production, and on Midrex (2009).

Figure 1. Iron Ore Deposits of Mexico

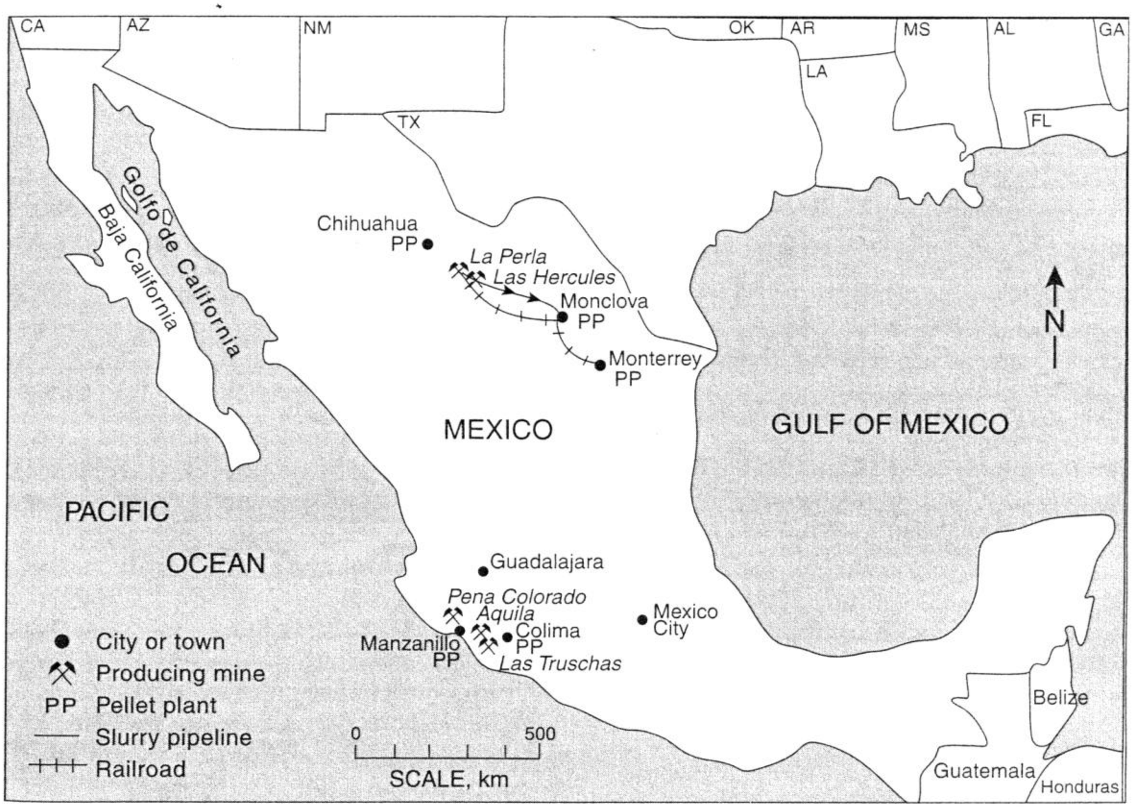


Fig. 8.8 Iron ore deposits of Mexico.

Source: AISE Steel Foundation, Making, Shaping, and Treating of Steel: Iron Making, 1999

Institutions Relevant to the Industry

The main iron and steel industry association in Mexico is the *Cámara Nacional de la Industria del Hierro y del Acero* (CANACERO). All of the major steel producers in Mexico are members of CANACERO. They provide confidential production and financial data to CANACERO which is aggregated across companies and then released to the public through public agencies in the Mexican government.

The Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT) is responsible for the protection of the environment and the sustainable use of natural resources. It sets standards for and collects data on the emission and release of various pollutants. SEMARNAT was also responsible for developing Mexico's climate change plan (Programa Especial de Cambio Climático 2009-2012) and co-sponsors a voluntary program for reporting of GHG emissions (Programa GEI México). Most of the major steel producers in Mexico participate in the GEI Mexico program.

The Secretaría de Energía de México (SENER) is the agency within the Mexican government that regulates and monitors energy production in Mexico. It also collects and publishes data on fuel consumption and electricity use by various sectors (including a "siderurgia" category, which includes iron and steel production and processing operations), which it publishes on its web site (http://sie.energia.gob.mx).

Instituto Nacional de Geografía y Estadística (INEGI) is the Mexican government's statistic office. Each year it compiles aggregate data on the Mexican iron and steel industry (including production, input use, and financial information) called "La Industria Siderúrgica en México." The report provides a very comprehensive set of data on the industry, including information on production, sales, trade, financials, and international comparisons.

II. Baseline Projections

This section projects Mexico's iron and steel industry CO_2 emissions in 2020 by the following steps:

1. Projecting 2020 BAU steel production.
2. Estimating the 2020 BAU route profile (shares of BF-BOF, DRI-EAF, and scrap-EAF production).
3. Estimating the current emissions intensity (tCO_2/tSteel) by route (BF-BOF, DRI-EAF, and scrap-EAF) – primarily based on GHG inventory submissions to Programa GEI México.
4. Estimating the 2020 BAU emissions intensity (tCO_2/tSteel) by route (BF-BOF, DRI-EAF, and scrap-EAF) – based on assumptions about improvements in existing plant and new build plant.
5. Estimating the 2020 BAU emissions (mt CO_2) by route (BF-BOF, DRI-EAF, and scrap-EAF) – calculated by multiplying steel production (by route) and emissions intensity (by route).

2020 BAU Production Projection

Mexico's steel production peaked at 17.6 mt in 2007 before declining as the world economic recession took hold in 2008 and, more sharply, in 2009 (see Table 3).

Mexican steel production has not kept up with domestic demand, and the country has therefore been a net importer of steel since 1998. In 2008, the industry announced a goal of reducing imports by investing US$10 billion in new capacity between 2010 and 2013.

An important potential source of future growth for the industry is the National Infrastructure Program (NIP) initiated by President Felipe Calderón's administration in July 2007. The program includes plans for upgrades to a wide range of existing structures as well as construction of new facilities. Planned projects include 100 roadway construction projects, new investments in 13 marine facilities, three new airports, and expansions to 31 existing airports (DOC, 2008).

CANACERO's revised forecast for Mexican crude steel production, as of the spring of 2010, includes a fairly rapid recovery from the low point in 2009 (which it estimates to be 14.0 mt). The trade association expects that production will bounce back to 15.3 mt in 2010 and jump above the previous peak production by 2011 (with 17.6 mt of output).

Double-digit growth is projected for 2012 and 2013, followed by a deceleration to an average growth rate of about 7% over the following seven years. In this forecast, crude steel output reaches 36.5 mt in 2020. CANACERO assumes that the proportion of production through various processes (BOF versus EAF) remains unchanged over this forecast period to retain flexibility in responding to changes in the price of production inputs, including pellets, scrap, gas and electricity.

Table 3. Production of Iron and Steel in Mexico (thousand tonnes)

Year	Total Crude Steel	Basic Oxygen Furnace (BOF) Steel	Electric Arc Furnace (EAF) Steel	Open Hearth Furnace (OHF) Steel	Blast Furnace (BF) Iron	Direct Reduced (DR) Iron
1980	7,156	2,669	3,088	1,342	3,639	1,636
1981	7,663	2,971	3,374	1,318	3,767	1,686
1982	7,056	2,905	3,071	1,080	3,598	1,505
1983	6,978	n/a	n/a	n/a	3,537	1,497
1984	7,560	3,422	3,206	933	3,809	1,448
1985	7,399	3,139	3,241	1,019	3,529	1,500
1986	7,225	3,463	2,908	854	3,725	1,420
1987	7,642	2,967	3,366	1,309	3,698	1,551
1988	7,779	3,286	3,564	929	3,639	1,686
1989	7,852	2,965	4,066	821	3,230	2,164
1990	8,734	3,530	4,491	713	3,665	2,525
1991	7,964	3,125	4,577	262	2,962	2,410
1992	8,459	3,744	4,715	--	3,404	2,321
1993	9,199	3,749	5,450	--	3,423	2,737
1994	10,260	3,834	6,426	--	3,501	3,216
1995	12,147	4,542	7,606	--	4,142	3,700
1996	13,196	4,731	8,441	--	4,229	3,794
1997	14,246	4,964	9,254	--	4,450	4,440
1998	14,218	4,960	9,253	--	4,532	5,584
1999	15,274	5,245	10,054	--	4,822	6,070
2000	15,631	5,236	10,395	--	4,856	5,589
2001	13,300	4,771	8,529	--	4,373	3,672
2002	14,010	4,117	9,894	--	3,996	4,741
2003	15,159	4,591	10,568	--	4,183	5,473
2004	16,737	4,762	11,975	--	4,278	6,345
2005	16,195	4,505	11,690	--	4,047	6,065
2006	16,447	4,188	12,590	--	3,790	6,167
2007	17,573	4,558	13,014	--	4,078	6,265
2008	17,209	5,011	12,198	--	4,450	6,012
2009	13,957	4,330	9,627	--	3,925	4,147

Source: WSA, Steel Statistical Yearbook, various years.

<u>2020 BAU Route Profile Projection</u>

The route profile of the anticipated growth in Mexican steel production is a matter of debate. In general, steel industries in developed countries (where capital stock turnover makes up a higher proportion of investment and consumption) are becoming more and more scrap based, and developing countries' industries are remaining ore-based due to a lack of scrap from capital stock turnover. Mexico has a relative lack of scrap, but this will change as the country develops. According to CANACERO, the Mexican industry also wishes to produce more steel for the automotive market, which requires higher grades and thus necessitates a higher proportion of ore-based raw material.[3] Mexico's long experience and expertise with the DRI-EAF route would allow the use of this route for the foreseen growth of high quality grades, if sufficient natural gas supplies were available.

Over a longer time frame, however, the production of steel from scrap (using EAFs) should become an increasing share of output from the sector, both because of increased availability of scrap in Mexico and increases in imports of scrap from the U.S. Greater stability in natural gas prices stemming from enhanced use of shale gas in Mexico and/or the United States[4] would tend to favor DRI.

Table 4. Iron and steel production and process route share assumptions in BAU

	2006-08 average	2020 forecast
Steel		
Production (crude steel)	17.1 mt	36.5 mt
Net Imports (semifinished & finished)	1.8 mt	
Iron		
Blast Furnace	4.1 mt	
Direct Reduction	6.1 mt	
Scrap Use	9.3 mt	
Route Profile		
BF-BOF	27%	31%
DRI-EAF	31%	35%
Scrap-EAF	42%	34%

Sources: CANCERO, WSA and CCAP

The following projections of steel production and process route profiles were used as the basis for the projections in this study.

- Overall steel production forecasts
  - 6.25% annual growth 2008-2020 (to 36.5 mt steel in 2020)
  - 3.00% annual growth 2020-2030 (to 49.2 mt steel in 2030)
- Route profile of all (existing and new) capacity through 2030
  - 31% BF-BOF; 35% DRI-EAF; 34% Scrap-EAF

[3] The requirement that higher grades of steel be ore-based is continually being challenged, as scrap-based steelmakers adopt techniques that enable them to produce higher quality products.

[4] Because Mexico gets the majority of its natural gas from the US and natural gas prices in Mexico are indexed by regulation to U.S. gas prices, the Mexican government relies on U.S. price projections (2005, SENER). In fact, the most recent 2010 Annual Energy Outlook shows increasing natural gas exports from the U.S. to Mexico over the coming decades as U.S. supply expands due to enhanced shale gas production and Mexico's growing demand for natural gas exceeds growth in domestic supplies. Even with growth in production, U.S. natural gas wellhead prices are projected to increase over time, from just over $4/TCF in 2010 to about $6 in 2020 and $7.30 in 2030 (AEO 2010, Figure 14). (All figures are in 2008 dollars.)

<u>Current Emissions and Emissions Intensity</u>

No publically-available, methodologically-consistent statistics or benchmark levels of CO_2 emissions are available for the iron and steel industry in Mexico or in most other countries.[5] Consequently, Mexico's steel industry emissions and emissions intensities are not precisely known. CCAP has estimated route-specific emissions intensities (tCO_2/tSteel) based on four companies' (ArcelorMittal, AHMSA, Ternium México, and Tenaris Tamsa) 2008 emissions submissions to Programa GEI México and production data in CANACERO's Ten Years of Steelmaking Statistics, 1999-2008 (Table 5). The data have one particular strength and several weaknesses in their use as an estimation basis. The strength is that they are based on the World Steel Association's CO_2 Emissions Data Collection methodology, a recently developed standard for consistent reporting of emissions data. The weaknesses are that the data: 1) are limited in number, covering only four companies and a single year, 2) cover very little of the scrap-EAF segment of the industry, 3) report corporate-level (rather than plant- or route-level) emissions, and 4) have not been verified by certified auditors. The production data also suffer from being reported at the corporate-level (rather than plant- or route-level).

[5] The World Steel Association's internationally-recognized calculation method and data collection effort began only in 2008; the raw data is confidential and no public report showing country-specific or production route-specific emissions performance has been published.

Table 5. Emissions intensity of Mexican iron & steel production by process route (2008)

Route	Direct Emissions Intensity (tCO_2/tSteel)	Indirect Emissions Intensity (tCO_2/tSteel)	Total Emissions Intensity (tCO_2/tSteel)	Electricity Consumption Intensity (kWh/tSteel)
BF-BOF	2.11	0.17	2.28	307
DRI-EAF	1.00	0.44	1.43	797
Scrap-EAF	0.40	0.47	0.87	868
Total	1.08	0.37	1.45	683

Source: CCAP estimates, based on Programa GEI submissions, IEA GHG (2000), AIST (2010), IEA (2007). Estimates based primarily on GHG inventory submissions to Programa GEI México from AMHSA, ArcelorMittal, Ternium México and Tenaris Tamsa. Note: only one data point for Scrap-EAF route.

Table 6. Emissions of Mexican iron & steel production by process route (2008)

Route	Direct Emissions (mt CO_2)	Indirect Emissions (mt CO_2)	Total Emissions (mt CO_2)
BF-BOF	10.6	0.8	11.4
DRI-EAF	5.2	2.3	7.5
Scrap-EAF	2.8	3.3	6.1
Total	18.6	6.4	25.0

Source: CCAP estimates, based on Programa GEI submissions, IEA GHG (2000), AIST (2010), IEA (2007). Estimates based primarily on GHG inventory submissions to Programa GEI México from AMHSA, ArcelorMittal, Ternium México and Tenaris Tamsa. Note: only one data point for Scrap-EAF route.

Mexico's heavy reliance on the gas-based DRI-EAF steelmaking route contributes strongly to lowering its overall emissions intensity relative to other steel-producing countries. However, like many other developing countries with limited scrap supplies, Mexico uses less scrap to produce steel, which raises its emissions intensity relative to many developed countries.

Because of the lack of publically-available, methodologically-consistent statistics or benchmarks, it is difficult to assess how Mexico's iron and steel industry emissions intensities compare with other countries or with Best Practice plants. Robust international comparisons are not possible. However, very rough estimates of emissions intensity by CCAP consultants and other analysts suggest that the Mexican industry's overall emissions intensity could be among the lowest of major producers. [6]

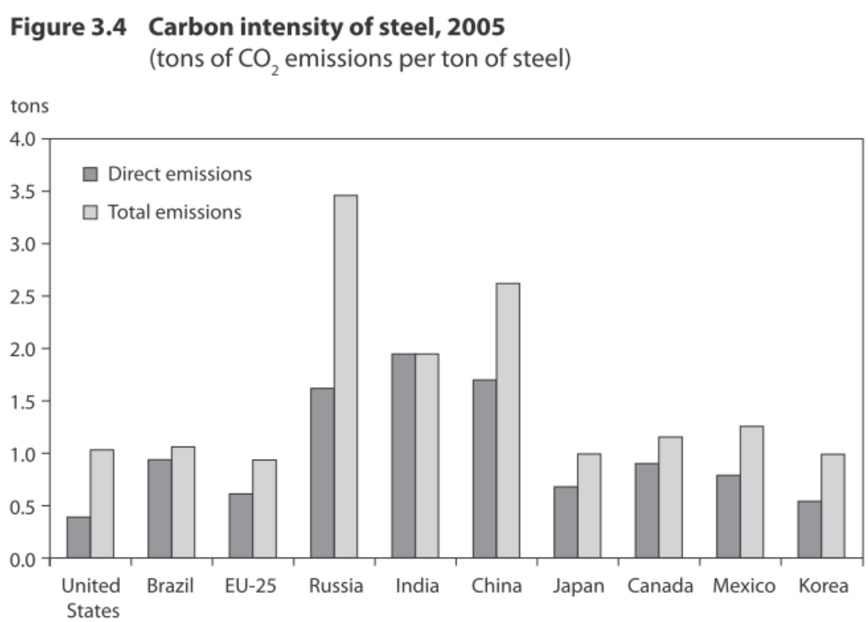
[6] These estimates are based on somewhat better data on energy use by the iron and steel industry – as reported by national governments to the International Energy Agency – from which CO_2 emissions can be estimated. However, these data are neither precise enough, nor verified as to accuracy and consistent industry definitions and plant boundaries, to provide anything more than a rough estimate of CO_2 emissions.

Table 7. Emissions intensity of iron and steel production, by process route (2005)

Country	Direct Emissions Intensity (tCO_2/tSteel)	Indirect Emissions Intensity (tCO_2/tSteel)	Total Emissions Intensity (tCO_2/tSteel)	Electricity Consumption Intensity (kWh/tSteel)
Mexico	0.94	0.26	1.19	500
US	0.96	0.44	1.40	848
Canada	1.17	0.36	1.53	700
EU27	1.32	0.38	1.69	733
Japan	1.58	0.32	1.90	617
China	2.35	0.37	2.71	715
India	1.40	0.37	1.77	716
Rest of World	1.74	0.52	2.26	1011
World	1.75	0.41	2.16	799

Source: CCAP estimates, based on IEA energy statistics, WSA steel production statistics; estimates should be considered very rough; embodying a high degree of uncertainty.

Nevertheless, this is highly uncertain, as the data presented in the figure below indicate that, among the major steel producers, only Russia, China and India have higher carbon emissions intensities than Mexico. As discussed above, Mexico's extensive adoption of the DRI process lowers its GHG emissions per ton of steel with respect to countries that primarily use the BF-BOF route, so comparisons of aggregate emissions intensities can be misleading. In other words, a low emissions intensity does not necessarily imply a lack of mitigation opportunities – efficiency improvements, process changes, CCS, alternative growth scenarios, and other measures may still be available for reducing GHG emissions.



Source: Houser et al. (2008), based on International Iron and Steel Institute (now World Steel Association), Steel Statistical Yearbook, 2006, IEA (2007c) and authors' estimates.

2020 BAU Emissions and Emissions Intensity Projections

Table 8. Emissions intensity of Mexican iron and steel production, by process route, in BAU scenario (2020)

Route	Direct (tCO_2/tSteel)	Indirect (tCO_2/tSteel)	Total (tCO_2/tSteel)	Electricity (kWh/tSteel)
BF-BOF	1.92	0.15	2.07	278
DRI-EAF	1.00	0.44	1.43	797
Scrap-EAF	0.36	0.43	0.78	782
Total	1.06	0.35	1.41	631

Source: CCAP estimates

Table 9. Emissions of Mexican iron and steel production, by process route, in BAU scenario (2020)

Route	Direct (mt CO_2)	Indirect (mt CO_2)	Total (mt CO_2)
BF-BOF	21.7	1.7	23.4
DRI-EAF	1.7	5.6	18.3
Scrap-EAF	4.4	5.3	9.7
Total	38.8	12.6	51.4

Source: CCAP estimates

III. Industry Mitigation Options

The mitigation options – and their potential emissions impacts, costs, and institutional and political viabilities – applicable to Mexico's iron and steel industry vary with two aspects of the sector. These are: 1) existing plant vs. new build plant vs. non-steel projects; and 2) the BF-BOF vs. DRI-EAF vs. scrap-EAF routes.

Existing plants have certain constraints as to technology, equipment, physical space and production schedules that make the implementation of major mitigation options – usually by retrofit – more costly and difficult than for a newly built plant. A new build, on the other hand, is inherently more modern and usually more energy efficient and less carbon intensive than an existing plant. It is also easier and less costly to implement mitigation options during the construction phase than during the operational phase. These factors mean there are narrower margins to best practice, or less room for improvement, in existing facilities. Non-steel projects can take many forms (e.g. constructing wind farms and improving forest management), and some companies may find them to be less costly methods of meeting emissions reduction goals.

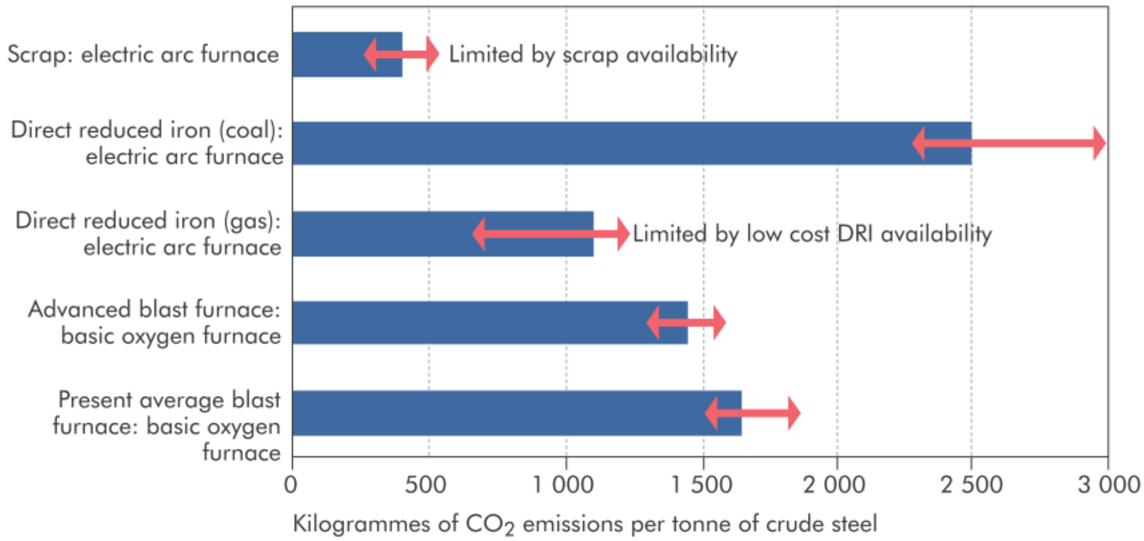
The main processing routes – BF-BOF, DRI-EAF, and scrap-EAF – also vary in their potential and methods for reducing emissions.

The BF-BOF route is the most carbon intensive, even in the most modern, well-equipped and well-run plants. It is also the most complicated route, involving the most sub-processes and equipment. Consequently, it has the greatest potential for inefficiency and poor emissions performance in less modern, less well-equipped, and less well-run plants. In Mexico, ArcelorMittal and AHMSA, large firms having extensive technical capabilities to be aware of and to implement mitigation options, operate three BF-BOF lines between their two plants.

The DRI-EAF route is less carbon intensive, when as in Mexico it is based on natural gas, and is somewhat less complicated than the BF-BOF route. Consequently, there is probably less potential to reduce emissions at existing gas-based DRI-EAF facilities than at BF-BOF plants. DRI-EAF is much less used throughout the world, so there is also less global attention to mitigation options. In addition, there are several different competing DRI-EAF reactor designs that further dilute attention and expertise. In Mexico, ArcelorMittal and Ternium México, again large firms having extensive technical capabilities to be aware of and to implement mitigation options, operate the four DRI-EAF lines (consisting of four HYL reactors, two HYL ZR (zero reformer) reactors, and one Midrex reactor) at two plants.

The scrap-EAF route is the least carbon intensive and least complicated, and generally has the fewest and smallest mitigation options, of the steelmaking routes. Scrap-EAF plants are generally smaller facilities and are operated by a wider range of firms – from large multinationals (e.g., ArcelorMittal) to mid-sized domestic firms (e.g., Deacero) to small domestic firms – having varying degrees of technical expertise for continued process improvement and implementation of mitigation options.

Figure 2. CO_2 emissions per tonne of crude steel produced



Note: The high and low-end ranges indicate CO_2-free and coal-based electricity, and account for country average differences based on IEA statistics. The range is even wider for plant-based data. The product is crude steel, which excludes rolling and finishing.

Source: IEA (2007)

Existing Plant Mitigation Options

As explained earlier, Mexico's steel industry emissions are not precisely known and cannot be compared with international best practice levels to gauge the potential for improvement. However, very rough estimates by CCAP and by Houser (2008)[7] suggest that the Mexican steel industry's average emissions intensity (tCO_2/tSteel) is near that of the world's better performers. The good emissions intensity level is primarily the result of the industry's heavy reliance on DRI, but also, as confirmed by visits to Mexican steel plants, of the industry being fairly modern (in some cases, very modern) and its implementation of several major mitigation options. This means that emissions reductions in the existing plants are of two types:

- smaller, low-cost reductions related to improved housekeeping, maintenance, and process scheduling, and further process optimization, and
- larger, high-cost reductions related to major mitigation equipment retrofits.

Both types are highly plant-specific, and require engineering audits for identification of mitigation actions and assessment of their emissions impacts and economic viabilities.

On February 7-12, 2010, CCAP visited five iron and steel plants from four companies in Mexico. These plants comprise 64% of Mexico’s capacity, and the companies as a whole account for 81% of Mexico’s capacity. The site visits provided first-hand evidence of the good technology base of the sector. There have been recent retrofits to all major processes and more investments are planned. Some of the plants have already implemented the technology changes suggested in the ICF Case Study of Sector-based

[7] Both the CCAP and Houser estimates are based on World Steel Association steel production statistics, International Energy Agency energy and emissions statistics, and authors’ estimates.

Approaches for the Iron and Steel Industry in Mexico, commissioned by CCAP as part of its Global Sectoral Study (see Appendix 2), as mitigation options in their lines of production as well as other energy saving technologies.[8] However, other opportunities to save energy and reduce emissions still exist. Housekeeping, process scheduling and heat retention/use improvements no doubt exist at all plants. The plant visits showed that some plants already have active programs to identify and make these improvements. Other major equipment upgrades that should be examined include: coke dry quenching (CDQ); BF top gas recovery turbines (TRT); BF natural gas injection; BOF gas/stream recovery systems at BF-BOF operations; improved furnace controls and scrap preheating at Scrap-EAF plants; thin slab and strip casting; and additional co-generation.

Fortunately, there appears to be a high awareness at the larger and higher emitting facilities of the importance of identifying and implementing these opportunities in operations and planning, and some process audits have been carried out recently.

In addition, four Clean Development Mechanism (CDM) projects have been developed. These process audits and CDM projects are an excellent starting point for the follow-on work of assessing plant-level emission reduction potentials and the costs of mitigation technologies, which could lay the foundation for the development of a sectoral NAMA that addresses existing facilities.

New Build Plant Mitigation Options

The high iron and steel production growth in the BAU projections for 2020 indicates that a large amount (13 to 19 mt) of new capacity will need to be built in the coming decade. This capacity will no doubt be more energy efficient and less carbon intensive than existing capacity, but further emission reductions can be obtained by ensuring that:

- a large amount of the new capacity uses the scrap-EAF route, within scrap availability, electricity availability and price, and finished steel product market constraints;
- a large amount of the new capacity uses the DRI-EAF route, within natural gas and electricity availability and price constraints;
- the new capacity is well equipped, encompassing all economically-viable mitigation options of the chosen processing route; and
- plants remain well-run and well-maintained, through attention to housekeeping, maintenance, process scheduling, and process optimization.

In the longer term, Mexico's iron and steel industry could prepare itself for the emissions profile necessary for longer term sustainability by participating in the development and

[8] The ICF Case Study of Sector-based Approaches for the Iron and Steel Industry in Mexico examined seven specific mitigation options (see Annex 2): pulverized coal injection in blast furnaces; natural gas injection in blast furnaces; hot feeding of DRI; hot feeding of DRI + high %C; DC furnace for EAF; scrap preheating – Consteel; scrap preheating - Fuchs shaft furnace; scrap substitution for DRI in EAF. These represent only a partial list of the mitigation options that might be applicable in Mexico. Upon follow-up investigation, several of these particular options were found to be of limited applicability in the Mexican iron and steel sector.

demonstration of "breakthrough" iron and steel making technologies and mitigation options.

Among the future emissions reduction technologies – consistent with a worldwide goal of reducing emissions by 50% by 2050 (compared to 2005) – that Mexico might consider testing and/or demonstrating are: smelting reduction; top-gas recycling blast furnaces; use of charcoal and waste plastic injection; production of iron by molten oxide electrolysis (MOE); hydrogen smelting; and CCS for blast furnaces, DRI, and smelt reduction.[9]

The technologically advanced state of the Mexican iron and steel sector implies that the available mitigation options likely have high up-front capital costs. A recent visit to Mexican iron and steel plants by the study team reinforced this notion. Other regulatory barriers also thwart implementation of these emission abatement options. For example, a lack of long term natural gas contracts discourages investment because future gas supply will be subject to the uncertainties of spot market prices. Also, the iron and steel sector faces relatively high electricity prices, impairing the competitiveness of electric arc furnace operations relative to those in other countries.

<u>Non-Steel Mitigation Projects</u>

CANACERO has expressed a desire to include mitigation actions outside of iron and steel plants as part of its NAMA. No further explanation was given about the actions being considered and how they might be supported, measured, and credited. However, off-sector emissions reductions could be recognized under any mandatory compliance program for the sector, including through a tradable intensity standard program or a new plant technology-based performance standard.

[9] These are example "breakthrough" iron and steel technologies cited in recent IEA publications (Energy Technology Transitions for Industry – Strategies for the Next Industrial Revolution (2009); Energy Technology Perspectives 2010 – Scenarios & Strategies to 2050) as being consistent with overall goals of reducing emissions by 50% by 2050 (compared to 2005).

IV. Development of NAMAs for the Iron and Steel Sector

The notion of Nationally Appropriate Mitigation Actions, or NAMAs, was first raised under the Bali Action Plan, for both developed and developing countries. Whereas developed countries were asked to consider "measurable, reportable and verifiable nationally appropriate mitigation commitments or actions, including quantified emission limitation and reduction objectives," developing countries were asked to consider "[n]ationally appropriate mitigation actions … in the context of sustainable development, supported and enabled by technology financing and capacity-building, in a measurable, reportable and verifiable manner." The Copenhagen Accord provided a forum for countries to commit to or announce NAMAs (for developed and developing countries, respectively) and established basic expectations for monitoring, reporting and verification.

Further, under the Copenhagen Accord, developed countries agreed to provide "scaled up, new and additional, predictable and adequate funding" for mitigation, adaptation, technology development and capacity building, including amounts approaching $30 billion over the 2010 to 2012 period. According to the World Resources Institute, as of June 5, 2010, a total of $31.32 billion[10] had been pledged by developed countries, with significant amounts of funding coming from Japan ($19 billion[11]), the European Union ($7.8 billion), and the United States (about $3.2 billion[12]). This "fast-start" finance will support developing country mitigation actions and adaptation through bilateral agreements as well as through multilateral channels.

The NAMA framework establishes a formal process for developing countries to adopt climate mitigation actions appropriate to their own circumstances and to acquire from developed countries the financing, technology, and other support needed for implementation. Through such cooperative efforts, it is hoped that NAMAs will make a substantial contribution to global efforts to reduce greenhouse gas emissions.

What Are NAMAs?

NAMAs are government regulations, standards, programs, policies or financial incentives that require or encourage individuals, organizations, companies, industries, or government agencies to undertake mitigation actions. NAMAs could cover one or more sectors or portions of sectors, and more than one NAMA could be proposed in a sector. Many types of NAMAs have been suggested, ranging from capacity-building NAMAs, to implementation of a specific mitigation technology, to advancement of a particular GHG-mitigation policy, and to overall sector or national emissions targets. Among these

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[10] There are questions about what share of these pledged funds are "new and additional" as called for under the Copenhagen Accord.

[11] $14 billion of this total is from public sources, with the remainder from private sources. Some of these funds may duplicate earlier pledges under the Cool Earth Partnership.

[12] Funds for 2012 are not included in this figure as they have not been requested as part of the United States budget process.

options, preparing packages of NAMAs at the sector level supports use of a single emissions baseline and simplifies quantification of emissions reductions.

While criteria for prioritizing supported NAMAs are likely to vary from one funder to another, it is anticipated that actions that achieve transformational policy changes, significant emissions reductions, deployment of advanced technologies, or implementation of innovative policy solutions will be most competitive. At the same time, in considering future actions for the Mexican iron and steel sector, it is desirable for Mexico to adopt programs that will encourage actions in the context of sustainable development, use resources wisely by achieving emissions reductions at least cost, and serve as a model for other developing countries.

There are three general categories of NAMAs: 1) unilateral; 2) supported/cooperative; and 3) credit-generating. These categories are differentiated on the basis of who pays for implementation and who takes credit for making the associated reductions. While the focus of this report is on identifying NAMAs in the Mexican iron and steel sector that might be competitive in winning financial support from developed countries (i.e., supported/cooperative NAMAs), a complete iron and steel mitigation program could include each of the elements below as well as capacity support.

1. *Unilateral NAMAs* – autonomous actions taken by developing countries to achieve emissions reductions without outside support or financing.
2. *Supported/Cooperative NAMAs* – developing-country actions undertaken with financial or other support from developed-country Parties, which result in more aggressive emissions reductions than unilateral NAMAs.
3. *Credit-Generating NAMAs* – actions that build on supported NAMAs, and by exceeding an agreed-upon crediting baseline, produce offsets for sale in the global carbon market.

Potential Government and Industry Mitigation Actions

CCAP's initial list of potential government actions for inclusion in an iron and steel NAMA for Mexico are shown in Table 10 (left column). These are mapped against the desired industry mitigation actions (top row) that they are intended to facilitate. Ultimately, some of these initial actions will be modified or excluded from the final NAMA proposal because of economic or political constraints.

Table 10. Map of Government and Industry Mitigation Actions

Industry Mitigation Actions / Government Actions (potential NAMA elements)	Existing & New Build Plant – Improved housekeeping, maintenance, and process scheduling and further process optimization	Existing Plant – Major mitigation equipment retrofits	New Build Plant – Increase share of capacity using the scrap-EAF route	New Build Plant – Increase share of capacity using the DRI-EAF route	New Build Plant – Ensure capacity encompasses all viable mitigation options of given process route	New Build Plant – Test/demonstrate "future" iron- and steel-making technologies	Non-steel projects
1. Require periodic energy/CO_2 audits of all existing plants; require/encourage implementation of viable mitigation obligations.	U	U&S					
2. Require/encourage formal plant energy and emissions management programs; develop/support energy management capabilities and infrastructure, including benchmarking.	U						
3. Establish a benchmarking system to MRV emissions performance for all (new and existing) plants; provide incentives for achieving best practice levels in all new facilities, including expansions.	U				U&S		
4. Improve natural gas availability to iron and steel plants through negotiations with PEMEX and/or US producers.				S			
5. Relax regulatory constraints on iron and steel plants' ability to self-generate electricity.		U		U			
6. Establish a government-industry partnership to develop a "Fast Start" Initiative to test and demonstrate future iron- and steel-making technologies.						S	
7. Establish a tradable intensity standards system, with transition to cap-and-trade.	C	C	C	C	C	C	C
8. Establish framework for crediting non-steel projects as industry actions within other elements.							U/C?

U = Unilateral NAMA; S = Supported/Cooperative NAMA; U&S = Unilateral for actions with costs less than threshold $/t$CO_2$ reduced and Supported for actions with costs greater than threshold $/t$CO_2$ reduced; C = Credit-Generating NAMA.

1. Require periodic energy/CO_2 audits of all existing plants; require/encourage implementation of viable mitigation obligations.

a. Description of government actions

- Government requires in-depth (much more thorough than simple walkthrough) energy and emissions audits to be carried out at all iron and steel plants by certified auditors.
- Government requires results of the audits and the recommendations for energy efficiency improvements and emissions reductions (with quantified benefits and costs) to be submitted punctually to the government for review.
- Government defines auditing effort guidelines (expected person-months as function of plant size and complexity) to achieve a high degree of thoroughness.
- Government develops auditor training and certification program – early rounds of audits might need to be conducted by foreign auditors to expedite the program
- Government requires companies to implement all recommendations below a specified \$a/tCO_2 reduced (at company expense), all recommendations between \$a/tCO_2 and \$b/tCO_2 (with government subsidies to buy down rate of return), under penalty of fines or denial of other benefits of NAMAs.
- Government seeks to engage external finances to buy down the rate of return of projects costlier than \$b/tCO_2.
- Government establishes in-house capabilities to review and critique audits and recommendations and a credible MRV program to track progress on implementation.
- Government offers audit subsidies and capacity support to smaller EAFs to support the associated management/project implementation/recordkeeping.

b. Industry mitigation responses expected

- Existing plants identify options for energy efficiency improvements and emissions reductions.
- Existing plants implement most economically attractive options with its own funds, and implement next most attractive options with government and external assistance.

c. Expected emissions reductions (absolute and intensity basis)

- 1-5% depending on plants and levels of incentives/assistance.

d. Costs of the actions (total, cost/product output and cost/tonne of emissions reduced) and share borne unilaterally and through external support

- Program costs of government include administration; technical expertise to review/critique audits and recommendations; auditing expense (subsidies if needed); auditor training and certification; and development of an MRV system
- Implementation costs by industry include upfront capital requirements; full net-present-value costs depend on threshold levels.
- Implementation costs by government – requires further research.

- Implementation costs by external sources – requires further research.

e. Co-benefits/costs, favored/disfavored facilities, and other implications

- Large firms are more capable of paying for audits, are less likely to uncover low-cost gains, and are more interested in buy down provisions
- Small firms are less capable of paying for audits and are more likely to uncover low-cost gains

f. Implementation barriers and government actions needed to overcome them

- Reluctance of firms to voluntarily undertake audits and implement recommendations – need requirements (but singling out iron and steel for regulation may not be legally feasible); may need incentives (such as creation and threat of denial of NAMA benefits)

g. Support needed from international community

- Funds for buy-down provisions of higher-cost mitigation options
- Funds to help subsidize audits?
- Assistance in training and certifying auditors
- Assistance in establishing MRV system

2. Require/encourage formal plant energy and emissions management programs; develop/support energy management capabilities and infrastructure, including benchmarking.

a. Description of government actions

- Government requires/encourages firms (larger than a certain threshold tonne/year production) to implement comprehensive energy and emissions management procedures and practices that encourage and facilitate systematic, continuous improvements in energy efficiency and emissions reductions. The procedures and practices include:
    - the development and implementation of a formal energy and emissions management policy and strategic plan to be reported to and overseen at company board level and reported in the company report;
    - the appointment of qualified energy managers at enterprise and plant-specific levels as appropriate; and
    - the development of maintenance checklists; manuals documenting projects; energy purchase and use procedures; measurement processes; performance indicators and benchmarks; progress reporting; energy coordinators; and demonstration projects.
- Government supports energy management capability through the development and maintenance of tools, training, certification and quality assurance.
- Government facilitates energy management capability through the development of a benchmarking program.

b. Industry mitigation responses expected

- Whereas the audits (Element #1) encourage companies to identify and implement mitigation options on a periodic basis, this Element is intended to encourage systematic, continuous improvement in energy efficiency and emissions reductions.

c. Expected emissions reductions (absolute and intensity basis)

- 1-2% depending on plants

d. Costs of the actions (total, cost/product output and cost/tonne of emissions reduced) and share borne unilaterally and through external support

- Requires further research.

e. Co-benefits/costs, favored/disfavored facilities, and other implications

- Requires further research.

f. Implementation barriers and government actions needed to overcome them

- Reluctance of firms to voluntarily implement energy and emissions management programs – need requirements (but singling out iron and steel for regulation may not be legally possible); may need incentives (such as creation and threat of denial of NAMA benefits).

g. Support needed from international community

- General policy advice from countries with wide experience with Energy Management policies
- Assistance in training and certifying energy managers
- Assistance in development and maintenance of tools, training, certification, quality assurance and benchmarking program

3. Establish a benchmarking system to MRV emissions performance for all (new and existing) plants; provide incentives for achieving best practice levels in all new facilities, including expansions.

a. Description of government actions

- Government, in consultation with international experts, develops and implements an energy and emissions benchmarking program for the iron and steel sector.
- Government collects the necessary data to monitor plant performance against the benchmarks.
- Government publishes results (publically and privately to companies) in ways that do not compromise confidentiality.
- Government reviews new plant construction plans and assesses design performance against the benchmarks.
- Government provides incentives (standards, tradable credits, permitting fast tracking, subsidies, etc.) to new plants to meet or exceed benchmarks.

b. Industry mitigation responses expected

- Design and construction of new plants more likely to implement best practice mitigation options.

c. Expected emissions reductions (absolute and intensity basis)

- 2-5% of new build plant emissions, depending upon plant and level of incentives/assistance.

d. Costs of the actions (total, cost/product output and cost/tonne of emissions reduced) and share borne unilaterally and through external support

- Moderately high (depends on ambition of incentives) – assuming that all low cost options are in base plan – but lower than implementing similar options as retrofits to existing capacity.

e. Co-benefits/costs, favored/disfavored facilities, and other implications

- Favors firms that are expanding.

f. Implementation barriers and government actions needed to overcome them

- Requires strong in-house technical capabilities to understand options and combat gaming and probably strong incentives to move to true world class performance.

g. Support needed from international community

- Financial incentives (depending upon level of ambition).

4. Improve natural gas availability to iron and steel plants.

This option would require considerable technical/economic study in addition to legal/political considerations. Many factors affect how the Mexican iron and steel industry would react at a given natural gas price level. Ideally, the government would want to know the maximum price level at which DRI-EAF becomes attractive vis-à-vis BF-BOF in new investment. A NAMA based on an underestimate could lead to an industry windfall; an overestimate could result in the construction of little gas-based capacity. In a cursory look at the metallurgy literature, no citation has been found for a natural gas break price at which gas-DRI-EAF becomes attractive. Most authors speak of gas-DRI being attractive where there is "primarily cheap stranded gas" (IEA) or "abundant reserves of inexpensive natural gas" (MSTS:I, p. 763). However, there is no mention of how inexpensive gas must be for DRI to be preferred – probably because it depends on the price of coking coal, price of high quality scrap, the quality of available iron ore, the scale of the plant, among other things. In general, DRI is viewed as a substitute for high quality scrap in EAF steelmaking, not as a substitute for BF iron. In addition, DRI is at its most competitive at medium-sized facilities; large scales favor the BF ironmaking.

a. Description of government actions

- Government provides enhanced access to natural gas resources such as, for example, support for new pipelines to shale gas resources; support for regulatory relief on purchases of domestic gas; and incentives for long-term contracts with gas suppliers, through negotiations with PEMEX and/or US producers.
- Quantities and prices of natural gas made available to iron and steel companies would be principle decision factors.

b. Industry mitigation responses expected

- A higher proportion of new ore-based capacity would be installed as DRI-EAF instead of BF-BOF.
- Natural gas injection into BF would be more attractive in existing and any new BF-BOF plants.
- Increased cogeneration and straight power generation opportunities (assuming implementation of Element #5)

c. Expected emissions reductions (absolute and intensity basis)

- High; more research needed to quantify potential range of emissions reductions.

d. Costs of the actions (total, cost/product output and cost/tonne of emissions reduced) and share borne unilaterally and through external support

- High total costs, but cost/tonne probably lowest of large mitigation options.

e. Co-benefits/costs, favored/disfavored facilities, and other implications

- Requires further research.

f. Implementation barriers and government actions needed to overcome them

- Requires further research.

g. Support needed from international community

- US might be persuaded to offer an "in kind" supported NAMA – providing shale gas to Mexican iron and steel industry on preferential terms as NAMA support.

5. Relax regulatory constraints on iron and steel plants' ability to self generate electricity.

a. Description of government actions

- Government loosens constraints on large-scale industrial cogeneration and straight power generation capabilities.

b. Industry mitigation responses expected

- Greater self generation of electricity from waste gases and natural gas (this could be used as a pricing sweetener to Element #4, i.e., the industry might accept paying a higher price for natural gas, if it is allowed to self-generate electricity with some of the supply.

c. Expected emissions reductions (absolute and intensity basis)

- Depends upon how much power capacity (coal or natural gas) is displaced.

d. Costs of the actions (total, cost/product output and cost/tonne of emissions reduced) and share borne unilaterally and through external support

- Requires further research.

e. Co-benefits/costs, favored/disfavored facilities, and other implications

- Makes Element #4 more attractive.

f. Implementation barriers and government actions needed to overcome them

- Great regulatory barriers exist here – requires further research.

g. Support needed from international community

- None needed.

6. Establish a government-industry partnership to develop a "Fast Start" Initiative to test and demonstrate future iron- and steel-making technologies.

a. Description of government actions

- Government or industry takes the lead in establishing a government-industry partnership to develop a "Fast Start" funded Initiative to test and demonstrate one or more future technologies that are key to long-term emissions reductions in the iron and steel industry.
- Fast Start Initiative would involve an extensive study phase to determine what technologies are most appropriate for Mexican context, and the location(s) where they would be tested and demonstrated.
- Fast Start Initiative would involve heavy consultation with major technology development efforts (e.g., ULCOS) in developing countries.
- Mexican government would negotiate with other governments in countries where new technologies are being developed to arrange a suitable package of technology sharing, financing, test results sharing, etc.

b. Industry mitigation responses expected

- Testing and demonstration of technologies that Mexican iron and steel industry could implement commercially in the medium or long term to establish an emissions profile consistent with long-term global and Mexican emissions goals.

c. Expected emissions reductions (absolute and intensity basis)

- None in short term; extensive in long term.

d. Costs of the actions (total, cost/product output and cost/tonne of emissions reduced) and share borne unilaterally and through external support

- Expensive.

e. Co-benefits/costs, favored/disfavored facilities, and other implications

- Requires further research.

f. Implementation barriers and government actions needed to overcome them

- Reluctance of international technology development consortia to share technologies.
- Requires government of Mexico and donor countries to negotiate suitable package of technology sharing, financing, test results sharing, etc.

g. Support needed from international community

- Technology sharing
- Financing

7. Establish a tradable intensity standard system, with transition to cap-and-trade.

a. Description of government actions

- Government plans and implements in medium term a tradable intensity standard system (foreseeing links to cap-and-trade systems in developed countries).
- Government establishes benchmarking system as per Elements #2 and #3.
- Government ensures that medium-term crediting does not undermine short-term mitigation actions.

b. Industry mitigation responses expected

- Requires further research.

c. Expected emissions reductions (absolute and intensity basis)

- Extensive in medium and long term.

d. Costs of the actions (total, cost/product output and cost/tonne of emissions reduced) and share borne unilaterally and through external support

- Requires further research.

e. Co-benefits/costs, favored/disfavored facilities, and other implications

- Requires further research.

f. Implementation barriers and government actions needed to overcome them

- Requires further research.

g. Support needed from international community

- General policy advice
- Coordination to ensure trading compatibility in global carbon markets.

8. Establish a framework for crediting non-steel projects as industry actions within other Elements.

CANACERO has expressed a desire to include mitigation actions outside of iron and steel plants as part of the NAMA. No further explanation was given about the actions being considered and how they might be supported, measured, and credited. However, off-sector emissions reductions could be recognized under any mandatory compliance program for the sector, including through a tradable intensity standard program or a new plant technology-based performance standard.

a. Description of government actions
Allow companies to credit non-steel projects within Element #7 or in lieu of some obligations in other Elements

b. Industry mitigation responses expected
- Requires further research.

c. Expected emissions reductions (absolute and intensity basis)
- Requires further research.

d. Costs of the actions (total, cost/product output and cost/tonne of emissions reduced) and share borne unilaterally and through external support
- Requires further research.

e. Co-benefits/costs, favored/disfavored facilities, and other implications
- Requires further research.

f. Implementation barriers and government actions needed to overcome them
- Requires further research.

g. Support needed from international community
- Requires further research.

<u>Potential Emissions Reductions of Proposed Government Actions</u>

The emissions reduction estimates, summarized in the Table 11 below, are illustrative of the potential of the proposed mitigation actions. They are based upon the following assumptions:

- **Overall steel production forecasts**
  - 6.25% annual growth 2008-2020 (to 36.5 million tonnes of steel in 2020)
  - 3.00% annual growth 2020-2030 (to 49.2 million tonnes of steel in 2030)

- **Route profile of all (existing and new) capacity through 2030**
  - 31% BF-BOF; 35% DRI-EAF; 34% Scrap-EAF

- **Emissions intensity by route, by existing capacity and new capacity**
  - Existing Capacity (no retirement)

    In BAU:

Route	Direct Emissions Intensity (tCO_2/tSteel)	Indirect Emissions Intensity (tCO_2/tSteel)	Total Emissions Intensity (tCO_2/tSteel)
BF-BOF	2.11	0.17	2.28
DRI-EAF	1.00	0.44	1.43
Scrap-EAF	0.40	0.47	0.87

    In NAMA example: a 2% reduction in all intensity values.

  - New Plant Capacity:

    In BAU:

Route	Direct Emissions Intensity (tCO_2/tSteel)	Indirect Emissions Intensity (tCO_2/tSteel)	Total Emissions Intensity (tCO_2/tSteel)
BF-BOF	1.76	0.14	1.90
DRI-EAF	1.00	0.44	1.43
Scrap-EAF	0.30	0.35	0.65

    This represents a 17% improvement (compared with existing capacity) for BF-BOF, a 0% improvement for DRI-EAF, and 25% improvement for Scrap-EAF.

    In NAMA example:

Route	Direct Emissions Intensity (tCO_2/tSteel)	Indirect Emissions Intensity (tCO_2/tSteel)	Offsets	Total Emissions Intensity (tCO_2/tSteel)
BF-BOF	1.20 + offset1	0.10 + offset2	- offset1 - offset2	1.30
DRI-EAF	0.90	0.40		1.30
Scrap-EAF	0.25	0.30		0.65

    This represents a 43% improvement (compared with existing capacity) for BF-BOF, a 9% improvement for DRI-EAF, and 37% improvement for Scrap-EAF.

Table 11. Summary of Steel Emission Reduction Potentials

Action	Details and Targets	Annual Emission Reductions (metric tons CO_2) in 2020	Annual Emission Reductions (metric tons CO_2) in 2030
1. Construction of New Iron and Steel Facilities			
1A Performance standards for all new steelmaking capacity	All new ore-based (e.g., BOF-BF and DRI-EAF) iron and steel capacity has emissions less than 1.3 tCO_2 / tCrude Steel, equivalent to the rate of a state-of-the-art natural gas-based DRI-EAF facility.	4,740,000	7,710,000
	All new scrap-based (e.g., Scrap - EAF) iron and steel capacity has emissions less than 0.55 tCO_2 / tCrude Steel, equivalent to the rate of a state-of-the-art scrap-EAF facility	490,000	920,000
1B Limited-term government subsidies (supports Action 1A)	Reflecting the carbon value of meeting the minimum performance standards instead of the business-as-usual emission rate		
1C Natural gas long term contracts (supports Action 1A)	Ensured ability to enter into long-term contracts for natural gas		
1D Demonstration-sized CCS facility (preparation for longer-term emissions constraints)	CANACERO would implement a demonstration-sized CCS facility, partially financed with international funds, at one of its associate's plants		
1E Offsets program (supports Action 1A)	Allows flexibility in technology of new construction, while meeting standards in Action 1A		
2. Existing Iron and Steel Facilities			
2A Energy/emissions management and benchmarking	Implementation of additional mitigation options from energy management programs, reducing the emissions intensity of new and existing plants by 1.0% over the period of 2020-2030	0	250,000
2B Energy/emissions audits and preparation of unilateral Plans of Action (supports Action 2C)	Mandatory energy and carbon intensity audits, submitted to government.		
2C Implementation of unilateral Plans of Action	Mandatory preparation of plans of action, submitted to government. Mandatory implementation of "break even" items in plans of action, reducing the emissions intensity of existing plants by 2%	520,000	520,000
2D Capacity building for energy/emissions auditing and management (supports Actions 2A, 2B and 2C)	Program capacity building, with international public support.		
TOTALS	All actions	5,750,000 (11.2% of BAU)	9,400,000 (13.8% of BAU)

BAU emissions are 51,430,000 mt CO_2 in 2020 and 68,170,000 mt CO_2 in 2030.

V. Measurement, Reporting, and Verification (MRV)

A number of international procedures and protocols have been developed for reporting of emissions in the iron and steel sector. In addition, methodologies for MRV of emission reductions for several types of iron and steel projects have been created under the Clean Development Mechanism (CDM). Some aspects of the MRV for CDM projects are not applicable to MRV for NAMAs, but other aspects are relevant.

A separate report under this project takes a broad look at MRV issues, including MRV for national inventory reporting, for fast-start finance, and NAMAs outside the iron and steel sector. The following discussion reviews a variety of MRV systems, including those currently in use in Mexico, specifically related to the iron and steel industry; any of these could serve as a model for MRV of a NAMA in Mexico's iron and steel sector. In the end, however, the specific MRV system to be required and adopted for such a NAMA will likely be decided by a negotiation among the steel industry, SEMARNAT and any entities providing international assistance.

IPCC Emission Reporting Guidelines for the Iron and Steel Sector

In 1996, the Intergovernmental Panel on Climate Change (IPCC) produced detailed guidelines for countries on the reporting of national emission inventories by Annex 1 countries (advanced economies) under the United Nations Framework Convention on Climate Change (UNFCCC). Those guidelines have been revised over time and supplemented by "Good Practice" guidance. In 2006, the IPCC issued a revised set of guidelines that incorporated all previous revisions and the good practice guidance. This section provides a brief summary of the procedures for emission reporting by the iron and steel sector in the 2006 IPCC guidelines as it might apply to the Mexican iron and steel industry.

The IPCC lays out three Tiers of reporting procedures. Tier 1 reporting involves national level production data and use of generic emissions factors. Tier 2 reporting involves national-level reports on production inputs and outputs and use of default carbon content values. Tier 3 involves plant-level reporting, using either facility-specific mass-balance methods (including plant-specific activity data, emissions factors and carbon contents) or direct emissions measurements. However, Tier 1 is not to be used if a sector is deemed to be a "key category" with respect to the current or projected share of total national emissions, and Tier 3 methods are preferred as they reflect plant-specific technology and process conditions. Notably, the IPCC does not specify use of unit- or process-level activity data at a given plant.

IPCC guidance also provides information on avoiding double counting of emissions with energy sector reporting and provides procedures for quality assurance/quality control, reporting, and documentation.

WSA Emission Reporting Protocol

The World Steel Association, in collaboration with the World Business Council for Sustainable Development, created a protocol for GHG emissions reporting by the iron and steel firms (see WSA). This protocol is used in the voluntary GEI reporting program in Mexico, as discussed in a later section.

The WSA emission reporting protocol involves calculating emissions by multiplying the quantities of inputs of a facility by their emission factors and subtracting the quantities of outputs multiplied by their factors. While the WSA reporting protocol asks the reporting entity to identify the number of each type of emitting units or processes employed in a facility, emissions are not estimated at the unit or process level. The protocol provides default emission factors, but suggests that more accurate estimates can be obtained – especially for coal and coke inputs, as well as ferro-alloy outputs, coke oven gas, and blast furnace gas – by direct measurement of carbon content and caloric values. Default emission factors are taken from the IPCC, the International Energy Agency, and in some cases the WSA itself.

Measurement of Emissions in the EU ETS

The Emissions Trading System of the European Union specifies the procedures that compliance entities must use in reporting their emissions (EC, 2007). Integrated steelworks are allowed to report emissions from the entire facility based on a "mass-balance" procedure similar to that employed by the WSA. The default emission factors are all from the 2006 IPCC guidelines. Compliance entities are given the option to make separate reports of the combustion and process emissions for each stage of production.

EPA's Mandatory GHG Reporting for the Iron and Steel Industry

The US Environmental Protection Agency (EPA) began requiring reporting of emissions in many industrial sectors in 2010. In the iron and steel sector, the EPA requires reporting by production facilities with CO_2-equivalent emissions over 25,000 tons per year (including combustion and process emissions as well as miscellaneous use of carbonates). The EPA requires each facility to report its annual production of taconite pellets, coke, sinter, iron, and raw steel. Emissions reporting requirements are discussed below (and see EPA, 2009).

Units that are required to report combustion emissions of CO_2, methane, and nitrous oxide include: byproduct recovery coke-oven-battery combustion stacks, blast furnace stoves, boilers, process heaters, reheat furnaces, annealing furnaces, flame suppression, and ladle reheaters. The emissions of methane and nitrous oxide are computed by multiplying fuel inputs by standard emission factors, the same approach as used for other stationary sources. Combustion emissions of CO_2 are to be measured with a continuous emissions monitoring system (CEMS), if available.[13] Otherwise, with some exceptions, CO_2 emissions are calculated from fuel use and the carbon content of fuels.[14]

[13] Reporting with the CEMS is required only if unit capacity is greater than 250 mmBtu/hr (or 250 tons/day municipal solid waste), it has operated more than 1000 hours in any year since 2005, its operation and

CO_2 emissions from flares must be calculated using the gas flow rate (either measured with a continuous flow meter or estimated using engineering calculations) and the heat content of the flare gas combined with default emission factors. In the absence of daily or weekly measurements, engineering estimates of the heat content during normal flare use and of the CO_2 emissions from each event exceeding a threshold level may be used. For emissions of methane and nitrous oxide from flares, the EPA provides default emission factors for coke oven and blast furnace gas.[15]

A facility must make separate calculations of the emissions from each of the processes it uses. Reports are required for the following processes: coke oven pushing, taconite indurating furnaces, basic oxygen furnaces, nonrecovery coke oven batteries, sinter processes, electric arc furnaces (EAF), argon-oxygen decarburization vessels, and direct reduction furnaces. Process emissions are to be calculated with a CEMS, if available. Otherwise, process emissions can be calculated using either the carbon mass balance method or a site-specific emission factor, described below. An exception is coke oven pushing for which the EPA provides an emission factor to be multiplied by the amount of coal charged to the coke oven.

The EPA specifies that the mass balance approach requires measuring, on an annual basis, the mass of each input and output that contributes more than 1% of the total input or output mass.[16] These mass numbers are multiplied by the weight fraction of carbon for that input or output, as provided by a supplier or as estimated from at least three samples taken during the year. The facility must specify whether laboratory analysis was employed to estimate carbon content and, if so, what method was used.[17] Separate procedures and equations are used for each type of reporting unit.

Alternatively, site-specific emission factors for each process can be used. These factors are determined in a performance test in which the CO_2 emissions are measured from all exhaust stacks for the process. The feed rate of materials or the rate of production during the test must also be measured. The test must involve sampling of representative performance. The minimum test period is three hours for taconite indurating furnaces, non-recovery coke batteries, and sinter processes. Tests must be performed for three

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testing is mandatory under other regulations, and it has a flow rate monitor and a CO_2 (or certified gas) monitor.

[14] Default emission factors are used for pipeline natural gas, distillate oil, and fuel burned by units with less than 250 mmBtu/hour capacity. No reports are needed for emissions from fuels that provide less than 10% of the annual heat output or from biomass (unless EPA has provided default high heating values and emission factors).

[15] The default emission factors for blast furnace gas and coke oven gas, respectively, are 274.32 and 46.85 kg/mmBtu for CO_2 and 0.1 gm/mmBtu in each case for nitrous oxide. The EPA uses the 2006 IPCC Guidelines in these cases. The EPA itself estimated factors for the methane content of coke oven gas (28%) and blast furnace gas (0.2%).

[16] Two fuels that are not reported in mass units are natural gas (which uses cubic feet) and liquid fuels (gallons).

[17] The testing standards in ASTM C25-06, ASTM D5373-08, ASTM E1915-07a, ASTM E1019-08, and ASM CS-104 UNS No. G10460, ISO/TR 15349, and ISO/TR 15349 are required for the relevant materials.

complete production cycles for basic oxygen furnaces, EAFs, argon-oxygen decarburization vessels, and direct reduction furnaces. Separate tests must be conducted for any operating conditions in which CO_2 emissions vary by more than 20% (such as routine changes in the sinter feed or change in the grade of product). The performance test report must include all data and information used to derive the emission factor.

Several steel industry representatives and their trade associations have objected to the EPA's requirement for separate process emission reporting. They prefer the simplified, lower-cost, facility-wide carbon balance approach that had been developed by the American Iron and Steel Institute (AISI). They pointed out that the AISI approach has achieved wide acceptance internationally. The AISI method estimates a single emissions number for a facility, including both combustion and process emissions. It focuses on the most carbon-intensive materials. Default values are used for the carbon content of the included inputs and outputs. The EPA points out that this approach omits estimating the carbon in important inputs and outputs, including iron ore, scrap, and steel.

The EPA chose not to adopt the AISI protocol because of the uncertainties regarding the carbon content default values and because of the many advantages of separate reports on emissions from each process. In particular, the EPA explains that the default values do not account for site-specific differences in feedstocks, fuels, combustion efficiency, and operating conditions. As a result, the uncertainties are greater than 25% in reported values (EPA, 2009). Moreover, the EPA believed it important to distinguish between combustion and process emissions and among the different types of processes at the same facility. Information at the process level is needed to compare data from different plants and to undertake verification tests. Such data also reveal the emission intensity performance of a process at the best plants. If those methods were adopted more widely throughout the sector, significant environmental gains could be achieved. Process level information thus provides the information that is needed to formulate environmental policies in the sector.

Mexican Domestic Reporting for Iron and Steel

Mexican iron and steel companies report energy and emissions data to several domestic agencies. Energy data are reported to SENER (the Secretaría de Energía de México). Pollutant emissions (including GHGs) are reported to the Registro de Emisiones y Transferencia de Contaminantes (RETC). In addition, the larger iron and steel producers (ArcelorMittal, AHMSA, Ternium México and Tenaris Tamsa) voluntarily report their company-level CO_2 emissions to Programa GEI México, a public-private initiative formed through a partnership between the Ministry of Environment and Natural Resources (SEMARNAT), the World Business Council for Sustainable Development (WBCSD), the World Resources Institute (WRI) and the Mexican Coordinating Council (CCE) through its Business Council on Sustainable Development (CESPEDES).

VI. Interaction of Mitigation Approaches with Other Sectors

Mitigation options for a particular sector need to be developed within the context of a low carbon development strategy for the country. The PECC has articulated a set of national climate change objectives for Mexico, but a further level of specificity is needed to work out possible conflicts among mitigation policies and programs across sectors of the economy. A broad cap-and-trade program, covering many economic sectors would allow for a common carbon price and cost-effective mitigation activities that span and implicitly take account of interactions among many sectors.

Until such a broad, multi-sector market-based approach is implemented, the policies or programs designed for one sector need to take account of interactive effects with other economic sectors. In the iron and steel industry in particular, issues arise over the use of natural gas in DRI production and the use of electricity in EAFs. It is government policy to require PEMEX to sell fuel oil to the power sector at subsidized prices. Electricity is then also sold to large industry, including iron and steel, at concessionary prices. Emission abatement in the power sector could potentially involve higher prices for fuel oil or a shift to natural gas for power generation. This could have two potential effects on the iron and steel sector. First, the cost of production using EAFs would rise. Secondly, the extra demand for natural gas by the power sector could create difficulties for the steel sector to obtain all the natural gas needed for the intended expansion of DRI production. In particular, domestic natural gas distribution capacities could become a constraint. Moreover, given that domestic demand already exceeds domestic production of natural gas, concerns could be raised over the extent of the country's dependence on imports of the fuel.

VII. Avenues for Further Work

This report provides background to the draft Nationally Appropriate Mitigation Actions (NAMAs) that Mexico's iron and steel industry and the Government of Mexico might pursue together for the purpose of reducing the sector's greenhouse gas emissions. At least three important aspects of a full framework for the Mexican Iron and Steel NAMA have not yet been elaborated.

I. Timelines for:
- Further study and refinement of NAMA policy elements and mitigation actions
- Negotiation of NAMA commitments
- Implementation of NAMA policy elements and mitigation actions

II. Measurement, Reporting and Verification (MRV) Systems
- Development and implementation of MRV for:
    - emissions reductions
    - programmatic aspects of commitments (e.g., undertaking audits, providing training, providing timely funding)

III. NAMA Governance
- How industry, government, and external financing stakeholders negotiate the details of, and commit themselves to carry out, the NAMA;
- How execution of the NAMA is overseen (e.g., governing board, executive committee, semi-annual progress reports, etc.);
- How mid-term decisions are taken (e.g., to adapt NAMA to changing circumstances); and
- How disputes are resolved (e.g., how noncompliance with NAMA commitments by industry, government, and external financing stakeholders is resolved and/or sanctioned).

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Appendix 1: Major Steel Plants in Mexico

Company	Plant	State	Processing Route
AHMSA	Monclova	Coahuila	BF-BOF
ArcelorMittal	Las Truchas	Michoacan	BF-BOF
ArcelorMittal	Lazaro Cardenas	Michoacan	DRI-EAF
ArcelorMittal	Cordoba	Veracruz	scrap-EAF
Ternium México	San Nicolas	Nuevo Leon	DRI-EAF
Ternium México	Puebla	Puebla	DRI-EAF
Ternium México	Apodaca	Nuevo Leon	scrap-EAF
Deacero	Celaya	Guanajuato	scrap-EAF
Deacero	Saltillo	Chihuahua	scrap-EAF
SIMEC	Guadalajara	Jalisco	scrap-EAF
SIMEC	Mexicali	Baja California	scrap-EAF
SIMEC	Apizaco	Tlaxcala	scrap-EAF
SIMEC	San Luis Potosi	San Luis Potosi	scrap-EAF
SIMEC	San Luis Potosi	San Luis Potosi	scrap-EAF
Tenaris TAMSA	Veracruz	Veracruz	scrap-EAF
Gerdau Sidertul	Tultitlan	Mexico	scrap-EAF
TYASA	Orizabo	Mexico	scrap-EAF
Aceros CORSA	Tlalnepantla	Mexico	scrap-EAF
Industrias CH	Tlalneplantla	Mexico	scrap-EAF
SIYUSA	Merida	Yucatan	scrap-EAF

Appendix 2: ICF Case Study Options

The ICF Case Study of Sector-based Approaches for the Iron and Steel Industry in Mexico (commissioned for the CCAP's Global Sectoral Study, which was funded primarily by the European Commission) examined seven specific mitigation options: pulverized coal injection in blast furnaces; natural gas injection in blast furnaces; hot feeding of DRI; hot feeding of DRI + high %C; DC furnace for EAF; scrap preheating – Consteel; scrap preheating – Fuchs shaft furnace; and scrap substitution for DRI in EAF. These represent only a partial list of the mitigation options that might be applicable in Mexico.

The Mexican iron and steel sector has invested heavily in modernization and is already quite energy efficient. While this limits the applicability of some of the lowest-cost iron and steel sector abatement technologies, a number of abatement options that reduce emissions and recover energy were thought to be relevant to the Mexican industry. Upon follow-up investigation and site visits to iron and steel plants in Mexico, most of the particular options examined by ICF were found to be of limited applicability in the Mexican iron and steel sector. Overall, CANACERO judged the ICF analysis to be too academic and not representative of the on-the-ground situation in Mexico. It is included here for completeness; the status of each ICF mitigation option in Mexico's iron and steel industry, based upon site visits, is given below.

1. Pulverized coal injection (PCI) in blast furnaces
Status in Mexico: already largely deployed.

This abatement technology involves the partial replacement of coke through direct injection of coal into a blast furnace. Iron-making is the most energy-intensive step in BF-BOF steel-making. Within this step, the production of coke is a major source of CO_2 emissions. One of the main energy efficiency measures in the iron making stage is the injection of non-coke fuels into the blast furnace. Blast furnaces usually have some type of supplemental fuel injection with coke. The most common fuels used are natural gas and pulverized coal (U.S. EPA, 1998). Pulverized coal injection replaces part of the coke used in blast furnace, significantly reducing coke production and energy consumed in coke-making, emissions from coke ovens, and associated coke oven maintenance costs.

Increased injection of pulverized coal requires additional energy for oxygen injection, coal, electricity, and equipment to grind the coal. Moreover, coke is still needed in order to support the chemical reactions that occur in the blast furnace. The maximum supplemental fuel injection depends on the geometry of the blast furnace and the quality of the iron. Maximum theoretical coal injection rates have been estimated at 280-300 kg/tonne hot metal (Worrell et al., 1999). In practice, the highest injection rates reached in the U.S. have been 225 kg/tonne (Worrell et al., 1999). Based on the current state of research and development of this option, it is assumed that the achievable rate for the Mexican industry is 225 kg/tonne hot metal. Energy savings of about 0.57 GJ per tonne of hot metal can be achieved at this injection rate (Worrell et al., 1999).

2. Natural gas injection in blast furnaces
Status in Mexico: not generally used because facilities are injecting pulverized coal (research indicates that it may be possible to couple gas injection with injection of coal).

Natural gas can also be injected into blast furnaces as a supplemental fuel to reduce emissions. In most steel producing countries, pulverized coal is preferred to natural gas as an additive because of its greater availability and lower price. However, the abundance of natural gas in Mexico may make natural gas a preferred supplemental fuel. Maximum injection rates are lower and operating costs are higher than if coal is used as a supplemental fuel. However, retrofit costs are comparatively lower and CO_2 emission reductions are more significant for natural gas use (Worrell et. al, 1999). A smaller amount of total coke can be replaced with natural gas as compared to PCI because of technical limitations related to the temperature of the blast furnace. The endothermic reactions that occur due to hydrogen present in natural gas can decrease the temperature of the blast furnace below what is suitable for chemical reactions associated with iron production. Therefore, additional oxygen enrichment or an increase in blast furnace temperature must be used to enable large injections of natural gas (Gupta & Sahajwalla, 2005).

3. Direct current furnace:
Status in Mexico: not generally used; this mitigation measure does not provide the originally predicted environmental benefits and is very expensive to implement.

A direct current (DC) arc furnace consists of an electrode (one or more) and an anode comprising the bottom of the furnace. During start up from cold conditions, a mixture of scrap and slag is used to provide an initial electrical path. Once this is melted, the furnace can be charged with scrap. Compared to alternating current (AC) furnaces, a DC furnace results in a more stable reaction and enhanced heat distribution in the furnace, thus reducing power requirements. Studies by the EPRI Center for Material Production have shown that power consumption can be five to ten percent lower than AC operation (EPRI, 1997a). DC furnaces also result in reduced tap-to-tap times (shorter periods to melt the steel) and lower refractory consumption, as well as electrode savings of about 50 to 60 percent (EPRI, 1991). The capital costs for DC furnaces are about 10-35 percent higher than those for AC furnaces (Worrell et al., 1999). However, the cost savings in operation and maintenance help achieve a positive payback in less than three years (EPRI 1991).

4. Scrap preheating
Status in Mexico: this option could be more extensively deployed.

In a normal EAF operation, about 20 percent of the total energy leaves the furnace in the form of waste gases (EPRI, 1997b). Scrap preheating using this recovered waste heat can reduce power consumption by offsetting some of the electricity that would otherwise be needed to heat the scrap in the furnace. Conventional preheating delivers the off-gases from the EAF to the scrap placed in the scrap-charging bucket through a pipe that opens into a hood over the bucket. Conventional systems suffer from various limitations, such as scrap sticking to buckets, short bucket life, poor temperature control, and minimal energy savings that do not justify the investment costs (EPRI, 1997b). Advances in technology have led to the development of more efficient scrap preheating systems. Two of these are addressed as abatement options for Mexico's iron and steel sector. These technologies can be deployed in both new plants and as retrofits in existing plants.

CONSTEEL process

(this is a proprietary technology; CANACERO objected to its promotion)

This process consists of a conveyor belt that relays the scrap down a tunnel into a preheating section. Off-gases from the EAF are directed to the pre-heater in a direction opposite to the scrap movement and fed into the bag house. Preheated scrap is then discharged into the molten steel bath of the furnace. Using this process, scrap can be preheated to a temperature of 600°F (316°C) (EPRI, 1997b). The arc in the EAF is mainly used to keep the bath molten. This scrap preheating system not only reduces electricity consumption by about 60 kWh/tonne and 90 kWh/tonne, for retrofit and new plants respectively; it also reduces tap-to-tap times, electrode consumption and flue-gas dust emissions (EPRI 1997b; Worrell et al., 1999).

FUCHS shaft furnace process

(this is a proprietary technology; CANACERO objected to its promotion)

The FUCHS Shaft Furnace is a batch preheating system that can be used with both AC and DC furnaces. Almost 100 percent scrap preheating is possible with this system, which employs both a "single shaft" furnace and a "double shaft" furnace. The double shaft furnace maximizes the advantages of the FUCHS system but can only be applied to new constructions (Worrell et al., 1999). The single shaft furnace is comprised of a vertical duct located on top of the EAF that channels the off-gases for use in preheating the scrap (Worrell et al., 1999). Studies have shown electricity savings of 18 percent and a production increase along similar lines (EPRI, 1997b). The double shaft furnace arrangement consists of two furnaces each with a shaft and one common electrode mast and set of electrodes to serve both furnaces. The dual furnace operation initially charges scrap to one furnace and its shaft. Then a second furnace is charged with scrap while meltdown is occurring in the first furnace. The off-gases from the first furnace are then used to charge the scrap in the second furnace and vice versa. This reduces tap-to-tap cycles to as low as 40 minutes. However, this also means short power-on times of about 32 to 34 minutes, which make scrap management and planning essential (EPRI 1997b).

The advantages of these scrap preheating systems are: reduced electrode consumption, yield improvement, increased productivity, and reduced flue gas dust emissions (which in turn reduce hazardous waste handling costs) (EPRI 1997b; Worrell et al., 1999).

5. Substituting scrap steel for DRI

Status in Mexico: already using scrap as much as possible.

This option evaluates energy savings by substituting scrap steel for DRI, and as such, is only applicable to the three Mexican DRI-EAF plants that use a majority of DRI in their electric arc furnaces. Replacing DRI with scrap steel can reduce energy requirements because DRI requires a significant quantity of natural gas to produce, while scrap steel is recycled. According to Kopfle et al. (2008), scrap steel is the least energy intensive input to an EAF. Scrap steel can be used as a substitute for up to 50 percent of DRI as a feedstock to the EAF. The remaining 50 percent feedstock must remain as DRI because DRI-EAFs are typically producing types of steel that are sensitive to the impurities in scrap.

6. Hot feeding of DRI

Status in Mexico: already largely implemented, but may be some opportunities for greater use.

This option involves continuously feeding hot DRI to the EAF just after it is produced from the DRI production module. In a typical plant, DRI is either allowed to cool and is then stored for later use in an EAF, or it is continuously fed into the EAF on a conveyer belt that allows the DRI to cool. Instead of using cold DRI, this option requires that hot DRI is supplied from the DRI production module directly to an adjacent EAF, significantly reducing power requirements for melting. For each 100º C increase in DRI temperature, electricity consumption can be reduced approximately 20 kWh/tonne crude steel (Kopfle et al., 2008), and electrode wear in the EAF will also decrease (Anderson, 2002).

7. Increasing carbon content of DRI

Status in Mexico: already largely implemented, but may be some opportunities for greater use.

This abatement option involves the optimization of DRI quality, specifically increasing the carbon percentage in DRI. Higher carbon in DRI has several advantages including reduction of iron oxide, decreased electricity consumption due to improved slag foaming, and increased EAF productivity (Sandoval & Kakaley, 2001). Currently, the Mexican iron and steel industry averages around 2.5 percent carbon DRI. In analyzing this option, ICF assumed that the majority of iron and steel plants in Mexico have the capability to utilize 3.5 percent carbon DRI, but that attempting greater than 3.5 percent carbon would require prohibitively expensive capital additions.